P–GJPO–758

Monticello Mill Tailings Site

Operable Unit III Remedial Investigation/ Feasibility Study Work Plan

Volume I

Draft Final

September 1995

U.S. Department of Energy
Grand Junction Projects Office

Work Performed Under DOE Contract No. DE–AC04–86ID12584 for the U.S. Department of Energy

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Work Prepared Under Contract No. DE-AC04-86ID12584

Prepared for
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Projects Office

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ACRONYMS

ACACL	Alternate Corrective Action Concentration Limits
AEC	Atomic Energy Commission
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
As	arsenic
ARAR	Applicable or Relevant and Appropriate Regulation
AWQC	Ambient Water Quality Criteria
BLM	Bureau of Land Management
BRA	baseline risk assessment
BSA	biological study area
bw	body weight
CERCLA	Comprehensive Environmental Response Compensation & Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLP	Contract Laboratory Program
cm	centimeters
cm^2	square centimeters
cm^2/d	square centimeters per day
cm^2/s	square centimeters per second
COC	contaminants of concern
COPCs	chemicals of potential concern
cps	counts per second
CRDL	Contract Required Detection Limits
CRP	Community Relations Plan
CRQL	Contract Required Quantitation Limits
csf	cancer slope factor
CSM	Conceptual Site Model
CV	coefficient of variation
DCG	derived concentration guidelines
DO	dissolved oxygen
DOE	Department of Energy
DQO	data quality objective
EA	Environment Assessment
EDE	effective dose equivalent
EE/CA	engineering evaluation/cost analysis
Eh	oxidation reduction
EPA	Environmental Protection Agency

ERA	Ecological Risk Assessment
ET	evapotranspiration
ETAG	Ecological Technical Assistance Group
FFA	Federal Facilities Agreement
FS	feasibility study
FSS	Far South Site
FSP	Field Sampling Plan
ft	feet
ft^2	square feet
ft^3	cubic feet
ft^3/s	cubic feet per second
g	gram
GJPO	Grand Junction Projects Office
gpm	gallons per minute
HEAST	*Health Effects Assessment Summary Tables*
HHRA	Human Health Risk Assessment
HLA	Harding Lawson Associates
HQ	hazard quotient
ICP	inductively coupled plasma/mass spectrometry
in.	inches
K	potassium
K_d	distribution coefficient
kg	kilogram
l	liter
LC_{50}	concentration at which 50% of exposed organisms die
LD_{50}	dose at which 50% of exposed organisms die
LDLos	lowest lethal dose
LOAEL	lowest observed adverse effects levels
LRL	laboratory reporting limits
MCL	maximum contaminant levels
MDL	method detection limits
MDRD	minimum detectable relative difference
mg	milligrams
MMTS	Monticello Mill Tailings Site
Mo	molybdenum

MRAP	Monticello Remedial Action Program
mrem	millirem
MVP	Monticello Vicinity Properties
μg/L	micrograms per liter
μR/hr	microroentgens per hour
NAS	National Academy of Sciences
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policies Act
NOAEL	no observed adverse effects level
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NSS	Near South Site
O&M	operation and maintenance
OU	Operable Unit
Pb	lead
PCB	polychlorinated biphenyl
pCi/g	picocurie per gram
pH	measure of acidity
PM_{10}	10 micrometers
Po	polonium
ppm	parts per million
PRG	preliminary remediation goal
PCOC	preliminary COC
QAPjP	Quality Assurance Project Plan
QA/QC	quality assurance and quality control
Ra	radium
RAO	remedial action objectives
RAS	Routine Analytical Services
R_d	laboratory K_d
RfD	reference dose
RI/FS	Remedial Investigation and Feasibility Study
RMS	root mean square
Rn	radon
ROD	Record of Decision
RPD	relative percent differences

RPM	Remedial Project Manager
RSA	reference study area
Rust	Rust Geotech
s	second
SARA	Superfund Amendments and Reauthorization Act
Se	selenium
semi-VOC	semivolatile organic compounds
SFMP	Surplus Facilities Management Program
SSAB	Site Specific Advisory Board
State	State of Utah
TBV	toxicity benchmark value
TCL	Target Compound List
TDLos	lowest toxic dose
TDS	total dissolved solids
Th	thorium
U	uranium
UCL	upper confidence limit
USGS	U.S. Geological Survey
UMTRCA	Uranium Mill Tailings Radiation Control Act
V	vanadium
VCA	Vanadium Corporation of America
VCONT	vertical conductance
VOC	volatile organic compound
yr	year

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Executive Summary

Background

This Work Plan presents the activities to be performed by the U. S. Department of Energy (DOE) for the Remedial Investigation/Feasibility Study (RI/FS) at Operable Unit (OU) III of the Monticello Mill Tailings Site (MMTS). The MMTS is located in San Juan County, Utah, in and near the City of Monticello. The MMTS consists of a former vanadium and uranium millsite, encompassing a 110-acre tract of land owned by DOE, and surrounding peripheral properties owned by DOE, the City of Monticello, and private parties.

The MMTS was placed on the National Priorities List (NPL) in 1986 because of elevated risk associated with the spread of contaminated materials related to the past milling activities. MMTS is being remediated in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The DOE, U. S. Environmental Protection Agency (EPA), and State of Utah (State) have entered into a Federal Facility Agreement (FFA) (DOE 1988b), pursuant to Section 120 of CERCLA/SARA. The DOE is the lead agency that provides principal staff and resources to plan and direct MMTS cleanup activities. Oversight of activities performed under the FFA is shared by EPA and the State with the EPA having ultimate responsibility and authority.

The MMTS has been divided into three Operable Units: (1) OU I, the millsite tailings and millsite property; (2) OU II, peripheral properties adjacent to the millsite; and (3) OU III, the Montezuma Creek canyon downstream of OU II. A Record of Decision (ROD) for MMTS, signed in 1990 by the FFA parties, stipulated that contaminated materials in OUs I and II would be excavated and placed in a nearby repository, and that a focused RI/FS would be conducted at OU III to address contaminated surface water and ground water emanating from OUs I and II, and the contaminated soils and sediment deposited downstream of OU II in and along Montezuma Creek.

Preliminary Findings

A number of studies have been conducted since 1955 on MMTS media including air, surface water, ground water, and Montezuma Creek soils and sediments. Inorganic analytes (specific metals and radiological constituents including gross alpha and beta) are associated with millsite activities. Existing media data were compared with benchmarks including preliminary risk-based concentrations (see Work Plan Section 4) and preliminary identified Applicable or Relevant and Appropriate Requirements (ARARs) such as promulgated safe drinking water standards. Media specified below will be assessed to estimate potential threats to human health and the environment:

Soil and Sediment - Four analytes are sporadically located in floodplain soils and sediments as apparent overbank flood deposits, and may exist in significant quantities of millsite tailings deposited in stock ponds and beaver ponds.

Arsenic	Beryllium	Manganese	Radium 226

Surface Water - Five analytes are present within Montezuma Creek or seeps emanating from the millsite. Surface water is not currently used as a potable water supply but is used for agricultural purposes.

Arsenic	Selenium	Uranium	Gross Alpha	Gross Beta

Upper Ground Water Flow System - Nineteen analytes are present at levels exceeding benchmarks beneath the millsite. Nine of the analytes (*) have migrated off the millsite at these elevated levels. The upper ground water flow system is not currently used as a potable or agricultural water supply.

Arsenic*	Nickel	Lead 210	Uranium 235
Beryllium	Nitrate	Polonium 210	Uranium 238
Lead	Selenium*	Radium 226*	Gross Alpha*
Manganese	Uranium*	Radon 222*	Gross Beta*
Molybdenum*	Vanadium*	Uranium 234	

Deeper Ground Water Flow System - There is no indication that millsite contaminants threaten the quality of the lower Burro Canyon aquifer. This aquifer is an alternative drinking water source to the residents of Monticello who derive their primary drinking water from surface water collected at Loyd's lake upstream of the MMTS.

Primary Project Goals

The primary goals of the focused OU III RI/FS are stated below:

1. Set millsite cleanup levels for non-radiological analytes protective of ground water.

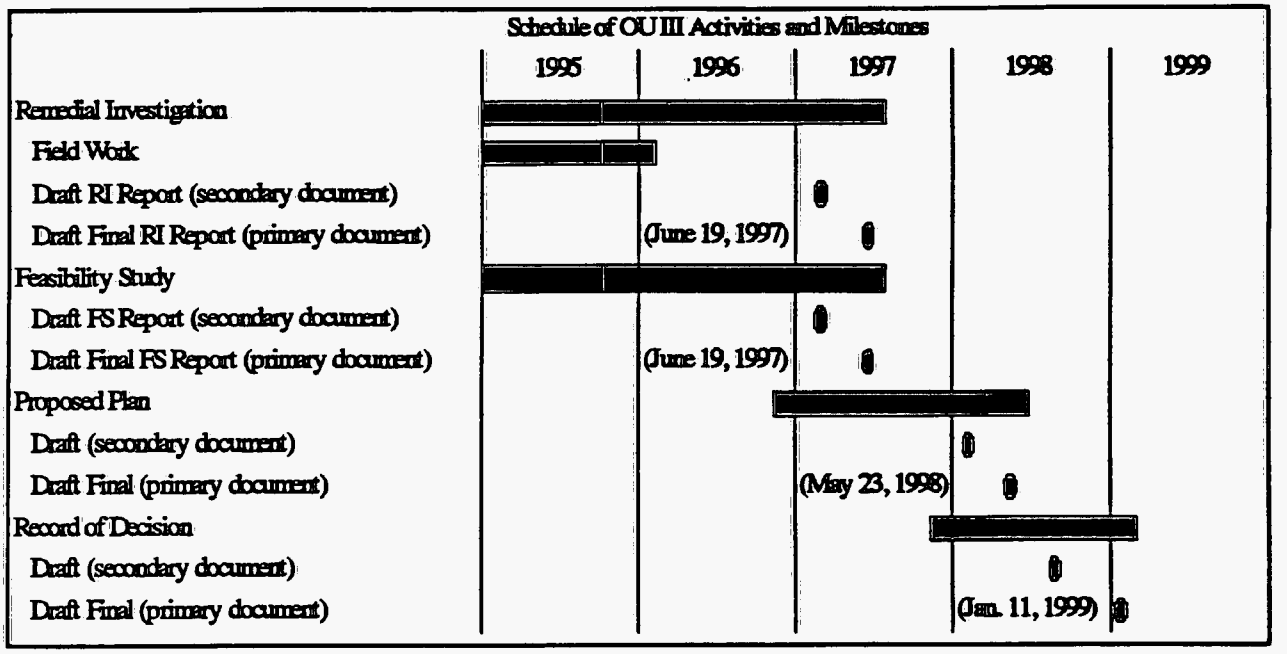
2. Develop and screen response action alternatives, including preliminary identified presumptive remedies, to protect human health and the environment under current and likely future land uses.

3. Select a preferred alternative(s), prepare a proposed plan, and incorporate public comment into the OU III record of decision.

DOE is also pursing an analysis of early action(s) for OU III in a separate streamlined risk evaluation (SRE) and engineering evaluation/cost analysis (EE/CA) consistent with the EPA's Superfund Accelerated Cleanup Model (SACM).

Schedule

The schedule for the RI/FS, proposed plan and record of decision is as follows:



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1.0 Introduction

This Work Plan, prepared for the U.S. Department of Energy (DOE) by Rust Geotech, presents the activities to be performed in support of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit (OU) III of the Monticello Mill Tailings Site (MMTS). The MMTS is located in San Juan County, Utah, in and near the City of Monticello (Figures 1.0-1 and 1.0-2). The MMTS consists of a former vanadium and uranium millsite, encompassing a 110-acre tract of land owned by DOE, and surrounding peripheral properties owned by the City of Monticello as well as private parties.

The MMTS is on the National Priorities List (NPL) and is being remediated in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The DOE, U.S. Environmental Protection Agency (EPA), and State of Utah (State) have agreed to perform activities at the MMTS in accordance with a December 1988 Federal Facility Agreement (FFA) (DOE 1988b), pursuant to Section 120 of CERCLA/SARA. The DOE is the lead agency that provides principal staff and resources to plan and implement MMTS activities. Responsibility for oversight of activities performed under the FFA is shared by EPA and the State; EPA is the lead agency with ultimate responsibility and authority but shares decision-making with the State (DOE 1988b, Section VIII.B).

The MMTS has been divided into three Operable Units:

- Operable Unit I - Millsite Tailings and Millsite Property. OU I consist of tailings impoundment areas and the area where the mill operations were conducted. Approximately 2.2 million cubic yards of contaminated material will be removed from OU I between 1996 and 1998 to a repository being constructed approximately 1 mile to the south, and the millsite restored to unrestricted access by 1999.

- Operable Unit II - Peripheral Properties. OU II consists of properties peripheral to the millsite that are contaminated by windblown or stream deposited tailings or by residual radioactive material from ore-buying stations or mill facilities. Contaminated material has been removed from peripheral properties since 1992, and an estimated additional 300,000 cubic yards of contaminated material still require removal and placement in the repository.

- Operable Unit III - Surface Water, Ground Water, and Contaminated Soil/Sediment in Montezuma Creek. OU III consists of contaminated surface water and ground water at and downgradient of the millsite and contaminated soils and sediment deposited downstream of OU II in and along Montezuma Creek. The RI/FS proposed in this work plan provides the remedial project managers with sufficient information to determine if response action is necessary to address any unacceptable risks in OU III, and to evaluate and select a preferred response alternative(s).

The OU III study area corresponds to the Montezuma Creek valley, extending east from U.S. Highway 191 to approximately 0.5 miles downstream of the confluence of Montezuma Creek and Vega Creek (Figure 1.0-3); presented at the end of this section. For purposes of this study, the upstream portion of the OU III study area (west of the point at which the canyon narrows) is referred to as Upper Montezuma Creek; the downstream portion of the study area (east of the point at which the canyon narrows) is referred to as Lower Montezuma Creek. Existing and new data collected downstream of the OU III study area (near the confluence of Montezuma Creek and Verdure Creek) will be used to assess risks posed by contaminants which have potentially migrated beyond the study area boundary. In addition, background samples will be collected in reference areas located along Verdure Creek and along Vega Creek (Figure 1.0-3).

As shown in Figure 1.0-3 (presented at the end of this section), the sediment component of OU III focuses on the segment of the Montezuma Creek floodplain extending from approximately 0.5 miles east of the eastern boundary of the millsite to the downstream boundary of OU III. The focused study area for sediment is referred to as the focused study area. The western boundary of the focused study area corresponds with the eastern boundary of Peripheral Property MP-00179. West of the focused study area, sediment contamination will be remediated under OU II.

Previous investigations have been conducted in and around the Monticello millsite and are summarized in Section 2 of the Work Plan. Results of these investigations provide the following general findings relative to the OU III project:

- Metals and radiological constituents are present in sediment and soil within the focused study area, and radionuclide concentrations exceed acceptable risk-based concentrations determined through preliminary site calculations (see Sections 4.5.2 and 4.6.3).

- Analyte concentrations in surface water and ground water within the upper ground-water flow system at and downgradient of the millsite exceed preliminary identified Applicable or Relevant and Appropriate Requirements (ARARs). Risk-based levels for the analyte concentrations have not been finalized. The upper ground-water flow system consists of the saturated Quaternary deposits and the upper, weathered portion of underlying bedrock. The system is further discussed in Section 3.4.1.

Contaminated sediment/soil and surface water/ground-water sources are the primary contaminant sources within OU III. The potential media of concern associated with these primary contaminant sources include sediment/soil, surface water, ground water, biota, and air. A preliminary screening assessment of potential risks associated with each potential medium of concern has been completed for the ecological and human health risk assessments (see Sections 4.5.2 and 4.6.3). The preliminary screening assessment involved computations of risk based on existing site information. Screening assessment results indicate that the air pathway is not a significant contributor to risk, and therefore, air can be eliminated as a media of concern. As a result, the media of concern for the OU III RI/FS include sediment/soil,

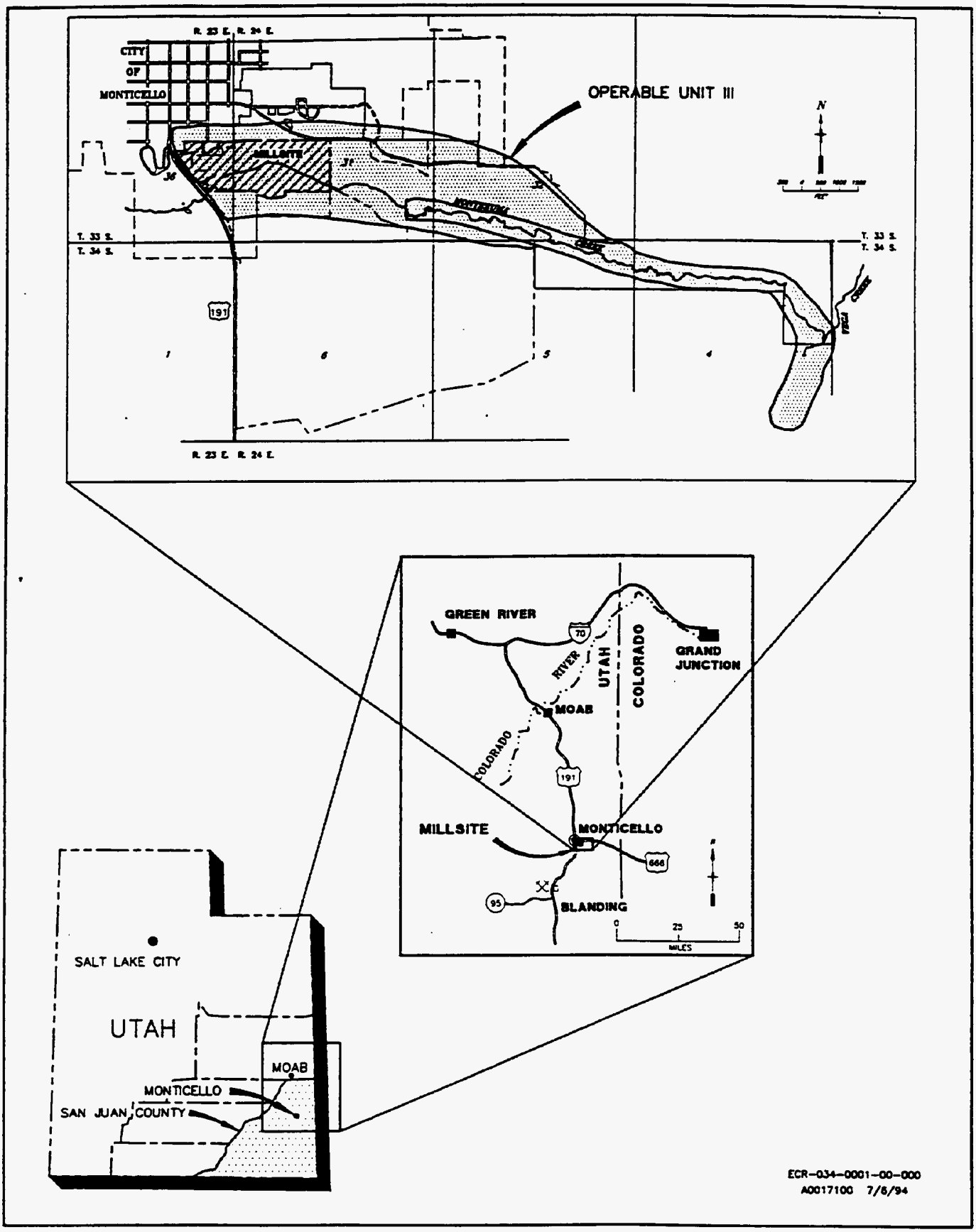

Figure 1.0-1. Regional Site Map

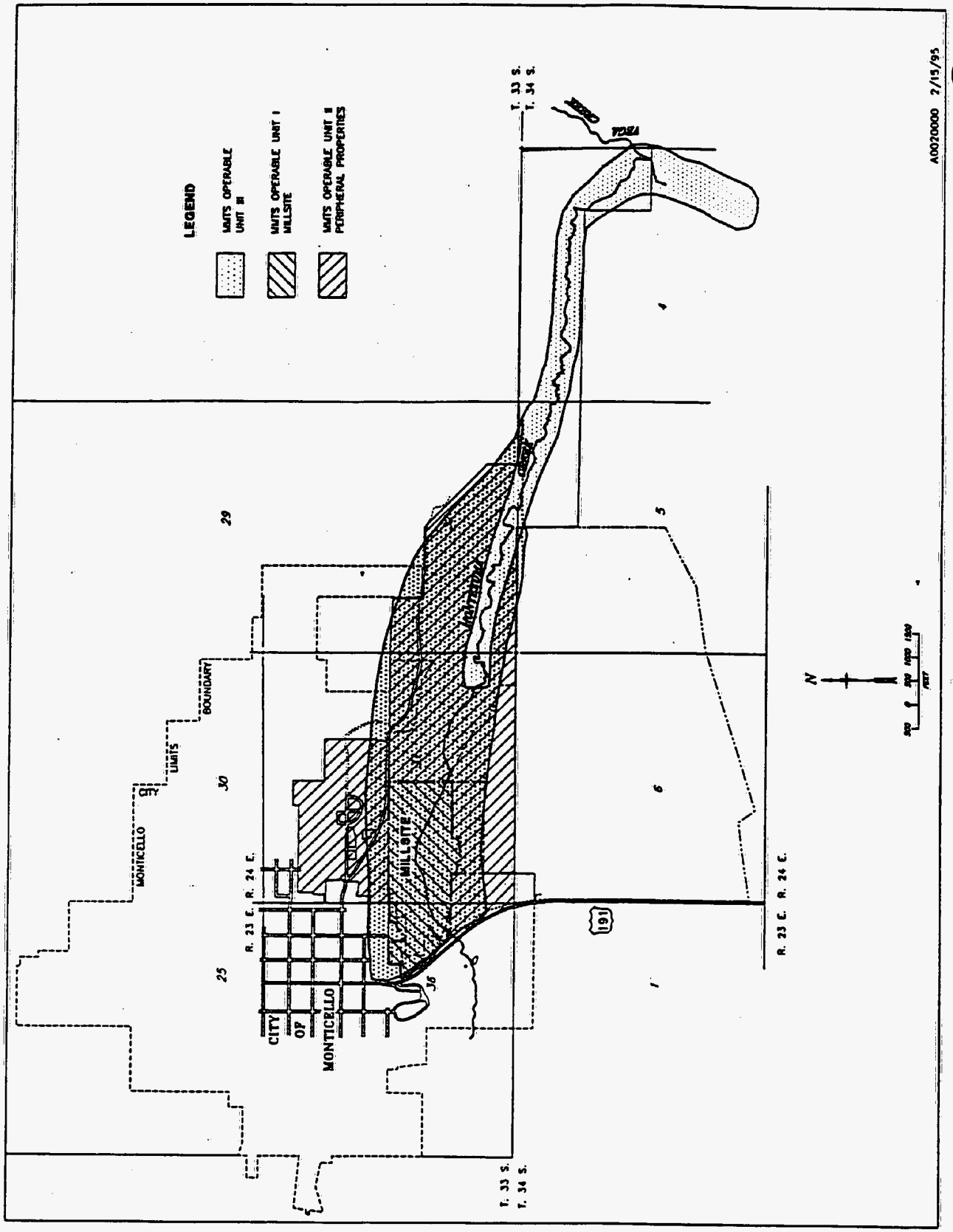

Figure 1.0-2. Location Map for the Monticello Mill Tailings Site

surface water, ground water (together referred to as abiotic media), and biota including plants and animals.

Human health and ecological risks will be assessed by comparing on-site concentrations of chemicals of potential concern (COPCs) to reference criteria. Reference criteria will include promulgated Federal and State standards, risk-based concentrations, background concentrations, and other "to be considered" criteria. For the human health risk assessment, it will be assumed that residential land use will likely occur within Upper Montezuma Creek but not in Lower Montezuma Creek. Risk-based concentrations for known or suspected cancer-causing substances (carcinogens) will be compared with the 1 in 10,000 to 1 in 1,000,000 (10E-04 - 10E-06) range for excess cancer risk specified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 Code of Federal Regulation [CFR] Part 300) corresponding with an individuals risk of an additional chance of getting cancer.

A significant amount of abiotic data and associated site characterization data have been collected within OU III and the surrounding area over the past several years. Although these data were not specifically collected to support risk assessment studies, the data were used during the preparation of this Work Plan to complete an initial screen of COPCs. These data have allowed DOE to provide more detail than normally found in an RI/FS Work Plan. The additional detail provided in this Work Plan will facilitate completion of the RI/FS.

1.1 Objectives

Assessment of OU III is complex because of the interaction between the focused study area, the surface and ground water, and ongoing remedial activities at OU I and OU II. The following goals and objectives are based on current understanding of these interactions and data uncertainties.

Four primary goals have been established for the OU III RI/FS. The first goal is to determine the ecological and human health risks posed by the sediment/soil contaminant source within the focused study area. The second goal is to determine the ecological and human health risks posed by the surface and ground water contaminant sources within OU III. The third goal is to collect sufficient quality data, as further defined in the data quality objectives sections of Section 4.0, to support evaluation of any response action alternatives.

The following specific objectives have been formulated to ensure these goals are accomplished:

- Collect the appropriate amount of additional data necessary to assess ecological and human health risks associated with applicable exposure scenarios. Preliminary exposure scenarios identified for the ecological and human health risk assessments are discussed in Sections 4.5.3.1 and 4.6.1, respectively.

- Refine lists of COPCs for the ecological and human health risk assessments using EPA guidelines, including comparison of on-site data to reference area data. COPCs for the ecological and human health risk assessments are discussed in Sections 4.5.3.3 and 4.6.4.2, respectively.

- Determine if cumulative COPC concentrations in each medium of concern within the focused study area for sediment pose an unacceptable risk to human health or the environment. If the risks are unacceptable, determine what concentrations of COPCs are acceptable and identify pertinent ARARs. Media of concern for the OU III ecological and human health risk assessments are discussed in Sections 4.5.3.1 and 4.6.1, respectively.

- Establish millsite cleanup criteria which specify the residual concentrations of COPCs in soil remaining at the millsite following remediation that will be protective of human health and the environment. The criteria will be established prior to completion of remediation under OUs I and II.

- Determine if current (pre-millsite remediation) COPC concentrations in surface water and ground water at and downgradient of the millsite pose an unacceptable risk to human health or the environment. If risks are unacceptable, determine what concentrations of COPCs are acceptable and identify pertinent ARARs.

- Develop a numerical model that adequately represents ground-water conditions, including ground-water and surface water interaction within OU III. The adequacy of the model will be determined on the basis of applicability to the decision-making process. Use the model to support post-millsite remediation temporal fate and transport and exposure-point concentrations for the ecological and human health risk assessments.

- Develop response action goals and alternatives and evaluate them in accordance with the criteria outlined in the NCP.

The data quality objective (DQO) process was used to design RI data collection activities. A general discussion of the DQO process is presented in Section 4.1. Application of the DQO process for studies designed to support the ecological risk assessment and human health risk assessment are discussed in Sections 4.5.4.1 and 4.6.4.1, respectively.

DOE will communicate preliminary results to the oversight agencies to address site characteristics which cannot be foreseen or planned for in the final RI/FS Work Plan. This observational approach will facilitate the DOE "Early Action" Strategy, in conformance with the EPA's *Superfund Accelerated Cleanup Model* (SACM) (EPA 1992c) approach, to identify

and implement appropriate early risk reduction in support of the final remedy at the site. Assessment decisions subsequent to the final Work Plan will be documented in an addendum to this Plan and addressed in the RI Report.

The goal of the final remedy will be to meet ARARs; however, if the requirements of the set goal cannot be achieved because of increased environmental damage, technical capability, cost, or other mitigating factors, ARAR waivers (alternative concentration levels or supplemental standards) and the justification to support them will be prepared.

1.2 Review of Work Plan Elements

This Work Plan is divided into three general parts as described below.

I. Background Information - The first three sections provide an overview of the site and previous investigation findings.

Section 1 - Introduction
Section 2 - Environmental Setting and Site History
Section 3 - Previous Investigations

- Sediment - soil analyses and gamma radiation exposure surveys
- Hydrologic - groundwater and surface water
- Ecologic - aquatic biology, vegetation, wetlands, and threatened and endangered species
- Air - radon, particulates, gamma radiation, meteorology, and off-site dose modeling

II. Task Descriptions - Sections 4, 5 and 6 describe the 13 major tasks that comprise the RI/FS. In italics are the corresponding task numbers for the EPA's list of fifteen standard tasks in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988a)

Section 4 - Remedial Investigation

- Project Planning *(Task 1)*
- Community Relations *(Task 2)*
- Baseline Characterization *(Task 6)*
- Ecologic Risk Assessment *(Task 6)*
- Human Health Risk Assessment *(Task 6)*
- Groundwater Modeling *(Task 3)*
- Annual Groundwater and Surface Water Monitoring *(Task 3)*
- Remedial Investigation Report *(Task 8)*

Section 5 - Feasibility Study
- Development of Alternatives *(Task 9)*
- Initial Screening of Alternatives *(Task 9)*
- Detailed Analysis of Alternatives *(Task 10)*
- Feasibility Study Report *(Task 11)*

Section 6 - Proposed Plan/Record of Decision *(Task 12)*

EPA standard tasks 13 (enforcement support) and 14 (miscellaneous support) are not applicable to this RI/FS. EPA standard tasks 7 (treatability study/pilot testing) and 15 (expedited response action planning) may be determined to be appropriate during the RI/FS and will be documented at that time as project directives appending this Work Plan.

III. **Schedule, Documentation and Control Components** -The remaining sections and plans address project schedule, documentation and control components of the RI/FS.

Section 7 - Project Schedule
Section 8 - Documentation
- Administrative Record
- Information Repository

Field Sampling Plan *(Task 3)*
Quality Assurance Project Plan *(Task 4)*

1.3 Project Organization

The relationship between the DOE management team and the Contractor Organization team for the OU III RI/FS is presented in Figure 1.3-1. The roles and responsibilities for the members of each team are outlined below.

1.3.1 Roles and Responsibilities for the DOE Management Team

The DOE-GJPO Monticello Projects Coordinator is the DOE formal point of contact for EPA, the State, and DOE-HQ on the Monticello Projects. On OU III, the Monticello Project Coordinator is supported by an OU III Project Manager.

The Monticello Projects Coordinator is responsible for the conduct of all activities for all Monticello projects. Responsibilities include integration of a schedule for all projects, oversight of the public relations and the community involvement initiatives, and cost and schedule control. The Coordinator negotiates milestones and submittal dates with EPA and the State on behalf of the DOE. The Coordinator communicates routinely with the EPA and State Project Coordinators on project progress and issues and represents the DOE at quarterly FFA Project Coordinator meetings.

Figure 1.3-1. Monticello OU III Organizational Structure

The Coordinator also has responsibility to provide formal monthly status reports to EPA and the State as well as to the DOE system.

The OU III Project Manager is responsible for oversight of all on-going activities and overall direction of the Contractor Organization. The Project Manager performs quality assurance review of all project deliverables and communicates with EPA and the State on technical issues concerning the project. The Project Manager reports directly to the Monticello Project Coordinator.

1.3.1 Roles and Responsibilities for the Contracting Organization Team

The DOE-GJPO Contractor Organization provides the technical resources required to conduct all projects under the jurisdiction of DOE-GJPO. The Monticello Projects are supported by personnel fully dedicated to only those projects so that the project requirements established by the DOE are met.

The Monticello Contractor Program Manager is responsible for implementing all project activities as directed by the Monticello Project Coordinator. The Program Manager is also responsible for all project submittals, DOE baseline budget and schedule management requirements, and support to the Public Relations and community involvement initiatives. Neither the Program Manager nor any other Contractor personnel have the authority to speak for DOE on project direction, schedule, issues, or policy.

The OU III Contractor Project Manager is responsible for oversight and guidance to all the project technical leads, coordination of all Contractor activities, and project budget and schedule management requirements. The Project Manager is the primary point of contact for direction of technical staff. The Project Manager is also responsible for coordinating scope and policy issues with DOE and Program Management. The Project Manager reports to the Program Manager.

Specific day-to-day activities are performed under the direction of established technical leads. Each technical lead serves as the point of contact for all work performed under her/his direction. In addition to technical leads, a health and safety coordinator and quality assurance coordinator ensure all work is performed in accordance with established procedures and guidelines.

Section 1.0

Introduction

Figures

September 1995

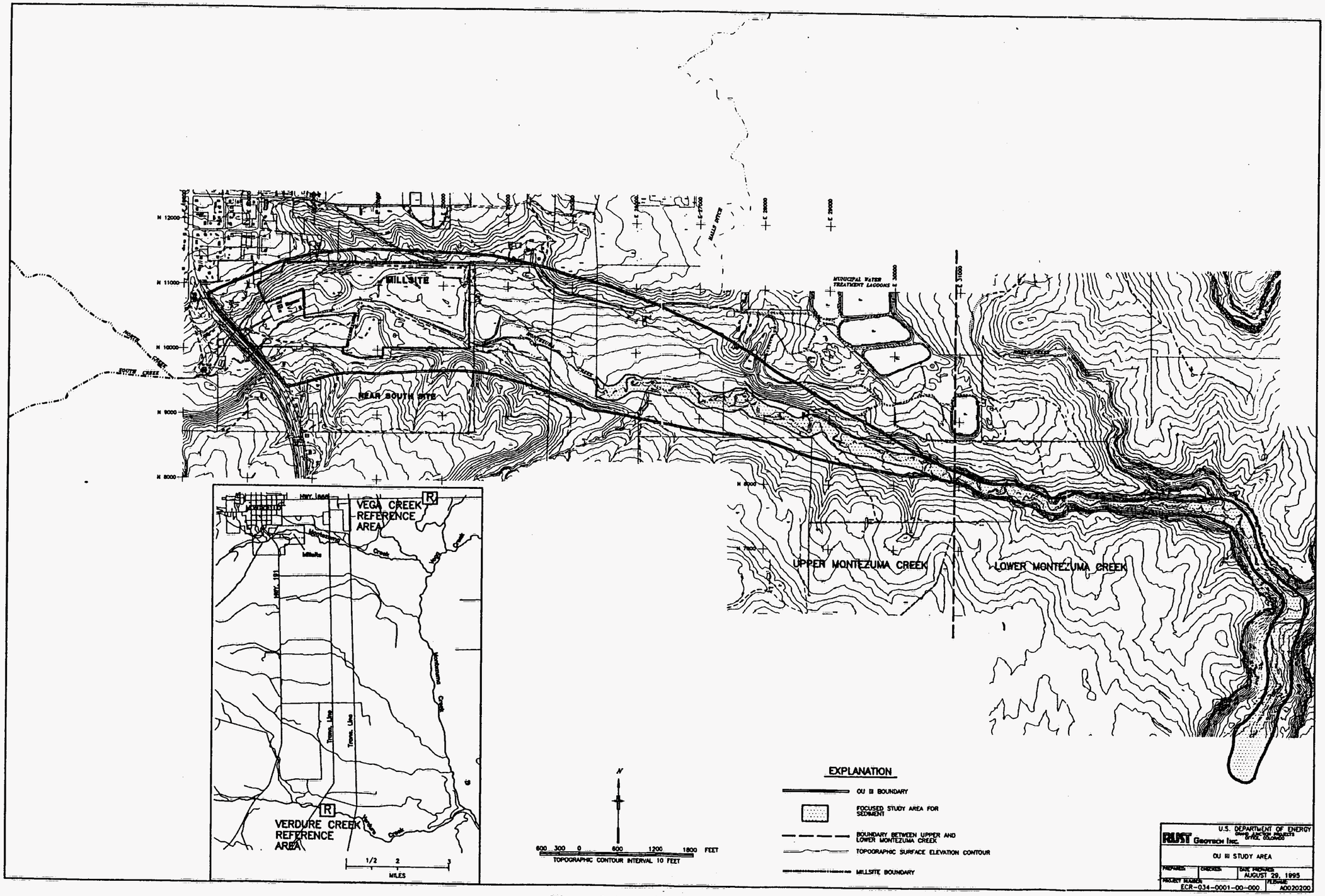

Figure 1.0-3. OU III Study Area

2.0 Environmental Setting and Site History

2.1 Environmental Setting

The numerous studies discussed in the previous section have provided a vast amount of information about the environmental setting in the vicinity of the MMTS. As a result, assessment of the environmental setting has been continuously refined over time and the discussion presented below was prepared based on information obtained from historical investigations and reports as well as from more recent studies. The recent studies include work performed in support of the OU III baseline characterization, OU I alternative analysis, and OU I conceptual design for the South Site repository. In addition, results of recent geologic mapping efforts were used to complete the geologic and hydrologic setting discussions.

2.1.1 Physiography

The MMTS is in the east-central part of the Colorado Plateau physiographic province. The site is in the south part of the Canyon Lands section according to the division of the Colorado Plateau by Fenneman (Fenneman 1931). The Abajo Mountains, Great Sage Plain, and Blanding Basin are the three physiographic subdivisions of the Colorado Plateau of Stokes (1977) that dominate the landscape in the Monticello area. Approximately five miles west of Monticello, the Abajo Mountains rise more than 4,000 ft above the broad, nearly flat, upland surface of the Great Sage Plain at about 7,000 ft in elevation. A canyon network of the upper part of Montezuma Creek and its tributaries incise the western part of the Great Sage Plain. The Montezuma Canyon network becomes more deeply incised as the creek flows to the south into the Blanding Basin.

2.1.2 Climatology

Climatic conditions of four distinct seasons typical of semiarid, mid-latitude steppes characterize the Monticello area. Winter is cold and windy with occasional heavy snows as well as short periods of below zero temperatures. Spring is a cool, unsettled, windy transition period during which snow can occur as late as May. Spring and early summer (April through June) are the driest months of the year. The mild late summer and early fall (late July to early October) are the wettest periods constituting the Southwest monsoon season. In the following sections, temperature and precipitation data for Monticello for the period from 1948 to 1994 are from the Utah Climate Center (Utah Climate Center 1994).

The annual average temperature is approximately 46°F. January is the coldest month with average high and low temperatures of approximately 35 and 13°F, respectively. July is the warmest month with average high and low temperatures of approximately 84°F and 53°F, respectively.

Average annual precipitation for Monticello is approximately 15 inches. During the period for records dating back to 1948, annual precipitation has varied from about 6.5 inches to about 23 inches. Precipitation that occurs as rainfall amounts to an average of about 10 inches annually; annual average snowfall is about 60 inches. Measurements by Utah State University of annual evapotranspiration (ET) and annual pan evaporation for Monticello are 43.84 inches and 42.3 inches, respectively (Andrews 1994).

Intense thunderstorms during which several inches of rain have fallen and floods have occurred can be seen in the daily precipitation records for Monticello. The largest amount of daily precipitation for Monticello was on August 1, 1968, when 3.38 inches of rain fell. This large thunderstorm and resultant cloudburst event affected the Monticello-Blanding area. Another thunderstorm and associated cloudburst occurred on September 5, 1970, and affected the area east and southeast of Monticello. On that date, Monticello received 1.62 inches of rain, but 20 miles to the southeast, Bug Point received approximately six inches of rain, a daily record for the State. This storm greatly affected the Montezuma Creek area, resulting in a tremendous peak discharge on the lower part of the creek near Bluff, Utah, of 52,940 cubic ft per second measured on September 6, 1970.

Large thunderstorms during which at least one inch of rain falls occur in Monticello an average of about once each year. Daily rainfalls of two inches or more are less common and have occurred on August 1, 1968 (3.38 inches), August 24, 1987 (2.50 inches), December 18, 1978 (2.40 inches from melted snow), July 31, 1956 (2.09 inches), October 19, 1949 (2.02 inches), July 20, 1969 (2.02 inches), and August 17, 1955 (2.00 inches). A two-day total of 3.11 inches on September 27 and 28, 1962, also is notable.

October, at the end of the Southwest monsoon season, can be an extremely wet month for Monticello. October 1972 was the wettest month in Monticello weather records, when 7.64 inches of rain fell (4.3 inches from October 15–20).

Prevailing winds are most commonly from the west-southwest, south-southwest, and northwest. Strongest winds are from the south-southwest and northwest and generally reflect large-scale, regional air-circulation patterns of daytime winds. Night winds are commonly from the west-southwest and reflect eastward drainage of cool air from the Abajo Mountains. Some of this nighttime flow is channelized and follows the valley of Montezuma Creek.

2.1.3 Geologic Setting

The region surrounding the MMTS is underlain by a thick sequence of Paleozoic and Mesozoic sedimentary rocks that mainly dip less than ten degrees to the east. These rocks rest on Precambrian crystalline basement that consists of metasedimentary and metaigneous rocks. Tertiary sedimentary rocks are not present in this area; they either were not deposited or were removed by erosion during middle and late Tertiary regional uplift of the Colorado Plateau. The Abajo Mountains, that rise about five miles west of Monticello, are the result of a cluster of laccoliths, of mainly granodiorite composition, that intruded the sedimentary rocks during Oligocene time. Unconsolidated deposits of mainly Quaternary age, consisting of pediment

gravel, loess, terrace gravel, and alluvium, cover much of the Mesozoic sedimentary rocks between the Abajo Mountains and Montezuma Canyon.

A map of the geologic units exposed in the MMTS area is shown on Plate 2-1. Geologic features along Montezuma Creek are generalized mainly from Huff and Lesure (Huff and Lesure 1965). These features do not reflect the results of detailed geologic mapping conducted by Rust in 1993 and 1994 in several areas between U.S. Highway 191 and the confluence of Vega and Montezuma Creeks. A refined geologic map is currently being developed on the recent geologic mapping and will be presented in the RI report.

Exposed rocks in the MMTS area dip gently (less than 2 degrees) to the east-northeast toward the axis of the subtle structure of the Monticello syncline. The synclinal axis strikes west-northwest, plunges eastward at a low angle, and is just north of the MMTS about one mile north of Montezuma Creek. The closest significant geologic structure to the MMTS is the Verdure graben about 4 to 5 miles to the south. Faults that define the graben and several en echelon normal faults just north of the graben strike eastward (Huff and Lesure 1965).

The Montezuma Creek valley above the confluence with Vega Creek was cut mainly during Quaternary time. West of U.S. Highway 191, the Montezuma Creek valley is cut into Mancos Shale of Late Cretaceous age. East of the highway, the valley cuts gradually into older rocks of the Dakota Sandstone of Late Cretaceous age and the Burro Canyon Formation of Early Cretaceous age. Approximately 0.5 miles upstream from the confluence of Vega Creek, Montezuma Creek begins cutting into the soft mudstones and shales of the Brushy Basin Member of the Morrison Formation of Late Jurassic age. Approximately one mile below the confluence of Vega Creek, Montezuma Creek begins cutting through more resistant sandstones of the Salt Wash Member of the Morrison Formation as shown in geologic mapping by Huff and Lesure (Huff and Lesure 1965).

Bedrock formations and unconsolidated surficial deposits described in this section are those units that are directly relevant to the characterization of ground-water and surface-water contamination. A generalized stratigraphic section and thickness of these sedimentary bedrock units exposed in the MMTS and adjacent areas are shown in Figure 2.1-1. Bedrock formations mentioned above, from oldest to youngest, the overlying surficial deposits of mainly Quaternary age, and structural geology are described below. Regional geology and geology specific to the millsite and the Near and Far South Sites are described in more detail in the *Monticello Remedial Action Project, Surface Geologic Characterization of the Near and Far South Sites* (Goodknight and Werle 1990) and in the RI/FS—EA (DOE 1990b).

2.1.3.1 Salt Wash Member of the Morrison Formation

The Morrison Formation in this area is composed of two members, the Salt Wash and the overlying Brushy Basin. The Salt Wash Member is composed of lenticular beds of light-colored, fine-grained sandstone interbedded with red mudstone layers. The sandstone was deposited as stream channels and makes up about 60 percent of the member. The mudstone

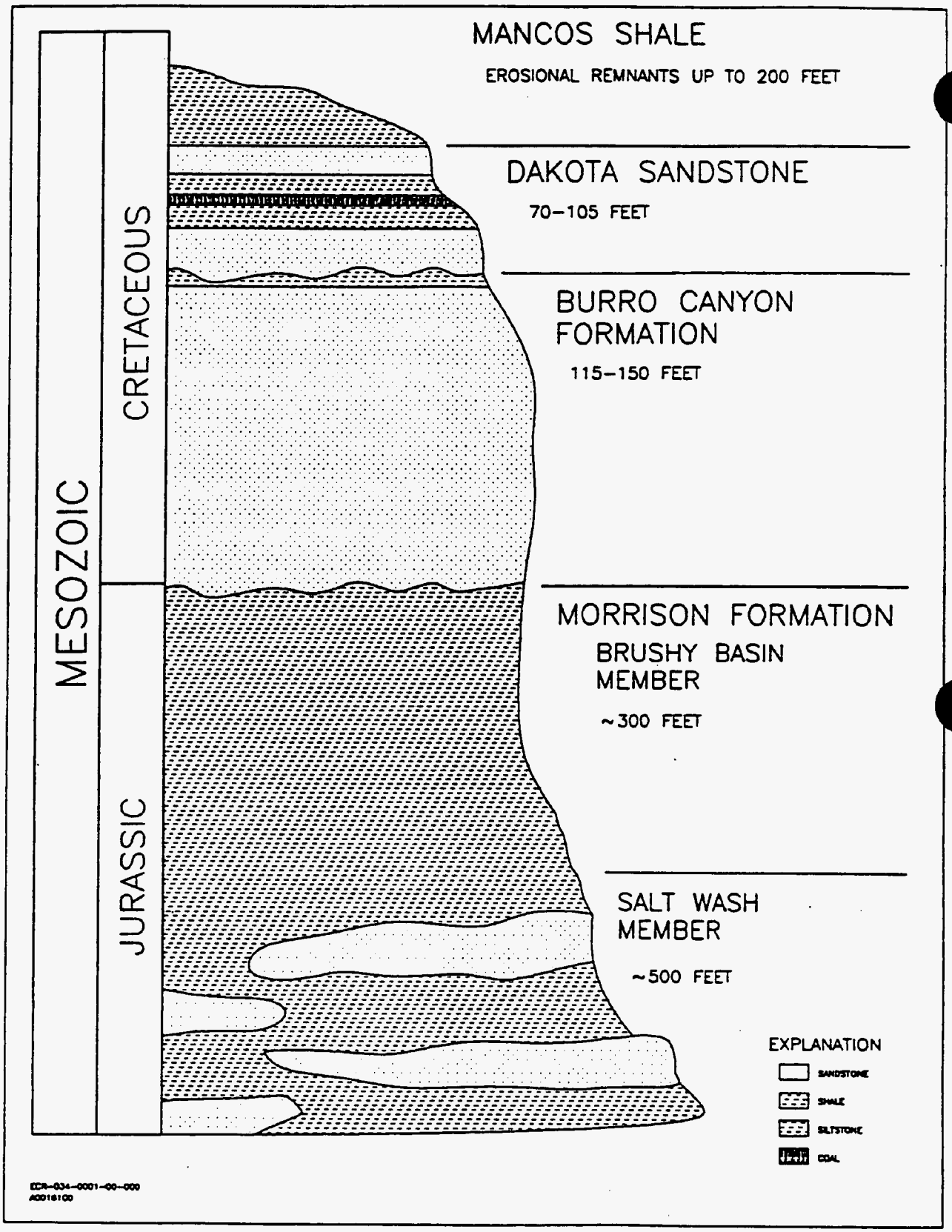

Figure 2.1-1. Generalized Stratigraphy and Thickness of Sedimentary Rocks Exposed in MMTS and Adjacent Areas

was deposited in a floodplain environment. Individual sandstone lenses are commonly 20- to 60-ft thick. Together, these rock types crop out as a step-like series of mudstone slopes and sandstone cliffs. The Salt Wash Member in the millsite area is approximately 500-ft thick. The gradient of Montezuma Creek steepens to approximately 300 ft per mile as it cuts through the Salt Wash Member; just upstream where the creek cuts through shales of the Brushy Basin Member of the Morrison Formation, the gradient is only about 150 ft per mile.

Uranium and vanadium deposits occur in sandstone, which represents stream-channel deposits in many locations where this rock type crops out south of OU III in Montezuma Canyon. These deposits are generally associated with carbonaceous material and also contain enriched concentrations of elements such as lead, molybdenum, selenium, cobalt, zinc, arsenic, nickel, and silver (Huff and Lesure 1965). Excluding the samples from the uranium/vanadium deposits in the Salt Wash Member, analysis of the content of uranium, vanadium, and several heavy metals (copper, lead, and zinc) from samples from the Salt Wash Member and younger formations (as young as Mancos Shale) indicates no significant difference in concentrations between the various formations (Huff and Lesure 1965).

2.1.3.2 Brushy Basin Member of the Morrison Formation

The Brushy Basin Member of the Morrison Formation consists of variegated gray, pale-green, red-brown, or purple bentonitic mudstone and claystone beds and minor, thin lenticular sandstone beds. Claystones and mudstones were deposited in a floodplain environment and the sandstones represent streams meandering over this plain. Exposures of this member are uncommon but do occur along lower Montezuma Creek downstream from approximately 0.5 miles above the confluence with Vega Creek (Plate 2-1). The nonresistant Brushy Basin rocks generally are covered by their own debris or by rock slides and colluvium from the resistant sandstone of the overlying Burro Canyon Formation. The Brushy Basin Member is approximately 300-ft thick in the millsite area.

2.1.3.3 Burro Canyon Formation

The Burro Canyon Formation unconformably overlies the Brushy Basin Member and forms a conspicuous and prominent cliff of sandstone that constitutes at least 90 percent of the formation in this area. The sandstone is white to light tan and is mainly fine to medium grained with minor beds of pebble conglomerate. Sandstone and conglomerate were deposited in a continental fluvial setting, and crossbedded units that are coarse-grained at the base and become finer grained upward are common. In some places, light-green silty mudstone occurs at or near the top of the formation. The mudstone, which may be silicified, represents over-bank deposits in interfluve areas. Silicification in the upper part of the formation occurred in both mudstone and sandstone in some places below the erosional unconformity that marks the contact with the overlying Dakota Sandstone. The thickness of the Burro Canyon Formation in the millsite area is approximately 115 ft based on one drill hole just east of the millsite and one drill hole in the Far South Site. Investigations by Craig (Craig 1982) show that the thickness of the formation in the Monticello area is variable and may reach up to 150-ft thick east of the millsite in upper Montezuma Creek.

2.1.3.4 Dakota Sandstone

The Dakota Sandstone comprises a variety of rock types, including conglomerate, sandstone, siltstone, mudstone/claystone, carbonaceous shale, and coal. In the millsite area, the

formation can be divided generally into three parts, as described by Huff and Lesure (Huff and Lesure 1965): a basal sandstone unit, a middle carbonaceous unit, and an upper sandstone unit.

The Dakota Sandstone unconformably overlies the Burro Canyon Formation. The basal sandstone unit locally contains conglomerates that occur in channels cut into the underlying Burro Canyon Formation. Channels may be as deep as 30 ft, but conglomerates are usually less than 10-ft thick and quickly pinch out in short distances laterally (Huff and Lesure, 1965). This lower unit is fluvial in origin and its thick, crossbedded channel sandstones are the most resistant and contain the best exposures in the formation. The lower sandstones have a high content of iron, which occurs as ferruginous concretions and as a coating of hydrous iron oxides on sand grains. Carbonaceous material sporadically occurs in the lower sandstone unit, but it is most common in the middle unit where all varieties and gradations occur between carbonaceous siltstone, carbonaceous shale, and coal. The middle unit is poorly exposed and represents a paludal or backwater/swamp environment. One or more impure bituminous coal beds up to 2-ft thick occur in the middle unit; these coal layers commonly contain sulfur along joint surfaces and contain several times the amount of radioactivity of the adjacent sandstones and siltstones.

The upper sandstone unit consists of fine- to very fine-grained sandstone and siltstone that represent littoral or offshore marine deposits of the transgressing Cretaceous Western Interior Seaway. These deposits grade upward into dark marine shales of the Mancos Shale; the top of the Dakota is the top of the uppermost fine-grained (bioturbated) sandstone bed.

The thickness of Dakota Sandstone in the millsite area varies from 70 to about 105 ft. This variation in thickness is because of variability in the thickness of fluvial sandstone sequences in the lower unit of the formation.

2.1.3.5 Mancos Shale

Remnants of Mancos Shale up to 200-ft thick occur below a cover of pediment gravels on gently sloping hillsides in the millsite area. The eastward extent of preserved Mancos Shale is approximately two miles east of U.S. Highway 191; west of that point, the thickness of Mancos Shale increases below the pediment gravel fan material. Exposures of the shale are poor and uncommon. This absence of exposed shale is because colluvium composed either of pediment material that has slid down or of weathered material of the Mancos itself has covered the shale.

The lower Mancos consists of gray to olive-gray calcareous shale, minor thin beds of gray calcareous siltstone, and several thin beds of white bentonite. The calcareous siltstones are

slightly more resistant and are the best exposed of the formation; the nonresistant bentonite beds are not exposed but are present in the subsurface. *Inoceramus sp.* and *Gryphaea newberryi* fossils are common in the lower 30 ft of the formation.

2.1.3.6 Unconsolidated Surficial Deposits

Pediment gravels, shed as alluvial fans from the Abajo Mountains during Quaternary and possibly as early as Pliocene time, form a cap over the Mancos Shale on the upland surfaces of the millsite area. This pediment material thins eastward and extends only to about two miles east of U.S. Highway 191. The pediment gravel consists of boulders as large as three feet in diameter and includes mainly cobble- and pebble-sized material. This material of various sizes consists of granodiorite porphyry, sandstone, silicified sandstone, and hornfels set in a finer-grained matrix of sand, silt, and clay. Several layers of reddish-brown loess occur in the pediment material and represent paleosol horizons. The loess layers are composed mainly of silt-sized windblown particles and each layer may be up to 8-ft thick. The pediment gravel and included loess layers may reach up to 100-ft thick in the center of the upland areas and along the west part of the millsite area near U.S. Highway 191.

A layer of loess up to 10-ft thick blankets much of the upland pediment surfaces north and south of the Montezuma Creek valley. Loess also covers much of the upland surfaces on bedrock east of the extent of the pediment fan material. The loess cover is thickest on the north side of gently sloping valley sides and is absent from south-facing slopes. This is a reflection of the origin of the loess from south winds that deposited thicker material in lee locations on the north sides of ridges.

Alluvial deposits along the Montezuma Creek valley consist of Quaternary deposits (alluvium) along the present course of the creek and terrace material at several levels along the sides of the valley that reflect former episodes of downcutting during the formation of the valley. Alluvial deposits along the creek are generally less than 20-ft thick, but locally occur in excess of 30-ft thick. The deposits consist of gravel, sand, silt, and minor clay. The terrace material is similar in size and composition to the pediment gravel.

2.1.3.7 Structural Geology

No evidence of faults has been seen on the surface or in the subsurface of the MMTS area. Systematic (regular in their arrangement) jointing is commonly seen in outcrops of Mancos Shale, Dakota Sandstone, and Burro Canyon Formation in the MMTS and nearby areas. Vertical, widely spaced joints are well exposed in the thick sandstone of the Burro Canyon in which the principal joint trend is east in the Montezuma Creek canyon area several miles southeast of the MMTS. Closer to the site, about one mile downstream from the millsite, the principal joint trend in the Burro Canyon Formation is east-northeast and vertical. A secondary, subsidiary vertical joint system at a 90-degree angle (orthogonal) to the principal joint trend is also present. No evidence for displacement has been seen along any of the surfaces of these systematic joints.

Fractures occur in the subsurface in the Mancos Shale, Dakota Sandstone, and Burro Canyon Formation. Fracturing exposed in the core from boreholes in the millsite area and the Near and Far South Sites is most common in the uppermost 20 to 30 feet of bedrock encountered. Fracturing occurs at greater depths, but it is infrequent. Most fractures seen in the core are subvertical and were either healed (filled) by secondary mineralization (mainly calcite and minor gypsum) or were discontinuous. Fractures oriented 30 to 45 degrees to vertical occur uncommonly; these fractures usually contain slickensides, are closed tight, and are healed by secondary mineralization. Where the Mancos Shale is the first bedrock encountered, horizontal fracturing along bedding planes is common, particularly in the zone of weathered Mancos Shale.

Four angled coreholes were drilled at 30 degrees from vertical in 1991 in the Far South Site to investigate the subvertical fracturing in the shallow bedrock of the Mancos Shale and upper 25 feet of the Dakota Sandstone. A conclusion from this drilling (Golder Associates, Inc. 1991) was that the fracturing in the lower Mancos Shale slightly increased the vertical permeability and hydraulic conductivity of the shale, although it still was classified as an aquitard.

2.1.4 Hydrologic Setting

This section summarizes the surface-water and ground-water hydrology at the MMTS and vicinity. The information presented is an interpretation of hydrologic data collected to date. Some supporting quantitative data are also presented. Section 4.7.3, Conceptual Model, discusses the interpreted behavior of the entire hydrologic system with specific regards to qualitative flow paths and magnitude.

The primary hydrogeologic units present in the study area include, from youngest to oldest, an upper ground-water flow system consisting mostly of Quaternary age alluvium and colluvium, an aquitard formed by the variably saturated, low-permeability Mancos Shale and Dakota Sandstone of Cretaceous age, and the Burro Canyon aquifer, also of Cretaceous age. Underlying the Burro Canyon aquifer is the Jurassic age Brushy Basin member of the Morrison Formation, which is considered relatively impermeable to ground-water flow.

Surface water at the site is present in the perennial Montezuma Creek and in seeps and ponds. The locations of monitoring wells and surface-water sampling sites are shown on Plate 2-2.

2.1.4.1 Upper Ground-Water Flow System

The upper ground-water flow system, also referred to as the "alluvial aquifer," consists mostly of saturated Quaternary deposits and the upper, weathered portions of underlying bedrock. Some hillslope colluvium and fill from previous millsite activities are presumed to make up minor portions of the upper flow system. At the MMTS, the Quaternary deposits are typically thickest in the central portion of the valley formed by Montezuma Creek and generally much thinner to nonexistent along the valley margins (if mill tailings are included, some of which

are saturated and within the upper flow system, thicknesses reach as much as 60 ft). Saturated thicknesses of the upper flow system range from approximately 2 to 25 ft, but generally are less than 15 ft.

The saturated Quaternary deposits are the primary conduits for ground-water flow within the upper flow system. A lesser component of ground-water flow in this system is expected to occur in the upper, weathered portion of bedrock, colluvium, and fill that underlies or coalesces with the Quaternary deposits at the flanks of upper Montezuma Canyon. Pumping tests conducted at wells 88-89 and 88-90, completed in the upper flow system, included the use of three observation wells each and resulted in best estimates of transmissivity of approximately 400 and 4,800 square feet per day (ft^2/day) (4.3 and 51.6 square centimeters per second [cm^2/s]), respectively. However, the larger transmissivity value is not considered representative of the upper flow system because the test is believed to have been influenced by recharge from Montezuma Creek. An estimated hydraulic conductivity, on the basis of the aquifer thickness at well 88-89 is 42 feet per day (ft/day), (1.5×10^{-2} cm/s) (DOE 1993b).

Previous slug testing was conducted in the millsite area in 1983, 1993, and 1994. Results obtained during the 1983 tests were identified as questionable because of the equipment and analytical method used. The 1993 tests were conducted in five upper flow-system wells (92-01, 92-07, 92-08, 92-09, and 92-11) upgradient and downgradient of the millsite; estimated hydraulic conductivities ranged from approximately 7.4×10^{-4} to 1.0×10^{-2} cm/s. As discussed in Section 3.0, 46 slug tests were conducted upgradient, on, and downgradient of the millsite during the summer of 1994. The range of the estimated hydraulic conductivity values for the 46 tests were 5.2×10^{-5} to 1.5×10^{-1} cm/s, and the geometric mean was 1.7×10^{-3} cm/s.

The lateral hydraulic gradient in the upper flow system ranges from 0.01 to 0.04 in the central portion of upper Montezuma Creek and from 0.08 to 0.10 along the valley margins. On the basis of constructed upper flow system ground-water elevation contour maps, ground-water flow is eastward in the upper flow system, parallel to the axis of upper Montezuma Creek. However, along the north and south margins of the valley, flow directions are more southward and northward, respectively, toward the valley's center (DOE 1994b and 1994b).

The primary sources of recharge to the upper flow system are infiltration of precipitation and surface water and lateral flow from upgradient sources. On the basis of ground-water modeling and environmental isotope measurements collected approximately one mile due south of the millsite, surficial recharges to the upper flow system are estimated to be approximately 1×10^{-9} to 1×10^{-7} cm/s (DOE 1994a). Well hydrographs indicate that some wells, particularly those located in areas where alluvium is thin, show occasional sporadic water-level fluctuations, probably because of relatively rapid recharge following a recent precipitation event. Upgradient sources of recharge include ground-water flow from alluvium and colluvium that mantles the North and South Creek watersheds on the east side of the Abajo Mountains west of the site. Most of the flow in the alluvial material in lower South Creek is regulated by flow or leakage from Monticello Reservoir (Loyd's Lake) (see Section 2.4.4). Secondary contributions of recharge are from lateral bedrock and colluvium sources on the

flanks of upper Montezuma Canyon. These sources include an undetermined amount of ground-water flow, and intermittent and perennial flow from seeps, springs and storm runoff.

Ground-water elevation contour maps (DOE 1994b) indicate that upper Montezuma Creek is a discharge area for shallow ground water in the area. Stream flow measurements indicate that discharge from the upper flow system occurs on various reaches of Montezuma Creek on the millsite and downgradient from the millsite.

Water levels in the alluvial aquifer fluctuate seasonally from low base-flow periods in the fall, to high-flow periods in the spring because of the effects of snowmelt runoff and in early winter from low-intensity, long-duration precipitation events.

Ground-water quality associated with the upper flow system is discussed in detail in the *Baseline Characterization Data Summary* (DOE 1994b) and summarized in Section 4.4 of this Work Plan.

2.1.4.2 Mancos Shale and Dakota Sandstone Aquitard

A bedrock-elevation contour map constructed using lithologic information obtained from boreholes drilled in the vicinity of the MMTS is presented in Plate 2-3. Comparison of bedrock elevation contour to surface contours indicates that bedrock topography tends to reflect surface topography. Also, the bedrock-elevation contour map indicates that bedrock elevations are generally lowest in the central portion of upper Montezuma Creek, where the thickness of Quaternary deposits is typically greatest.

The lower Mancos Shale outcrops along the flanks of the Montezuma Creek valley directly north and south of the millsite and forms bedrock west of and in the extreme northwest and southwest portions of the millsite. Mancos Shale occurs as outcrop in or near Montezuma Creek near Highway 191, west of the millsite. Subcrop Mancos Shale in these areas ranges from 0- to 30-ft thick, with the thickest areas generally located near the valley flanks. The Dakota Sandstone has one surface exposure on the millsite in the realigned portion (see Section 2.4.4) of Montezuma Creek south of the east tailings pile, and outcrops in upper Montezuma Creek about 0.5 mile east of the millsite. The Dakota Sandstone forms most of the bedrock east of and within the millsite in upper Montezuma Creek. On and in the vicinity of the MMTS, the Dakota Sandstone generally thins from the west, where it is approximately 105-ft thick, to the east, where it is nonexistent (approximately 0.8 miles east of the millsite boundary).

The Mancos Shale and upper and middle Dakota Sandstone are believed to act as an aquitard between the overlying upper flow system and underlying Burro Canyon aquifer at the millsite. The aquitard restricts flow between these primary flow systems. Data that support this hypothesis include poor to no yield from wells constructed in the lower Mancos Shale (200–3 at the millsite and 191, 192, 197–4, and 206–3 south of the millsite) and in the lower Dakota Sandstone (92–12, 92–13, 198–1, and 200–2 at the millsite and 197–3 south of the millsite). Other portions of the Mancos Shale and Dakota Sandstone have, at least locally,

indicated the presence of significant ground water. For example, wells 206-2 and 104-3 (located south of the millsite) constructed in the interbedded coal and carbonaceous siltstone of the middle Dakota Sandstone, have shown confined ground-water conditions. In addition, the extreme lower 2 to 15 ft sections of the lower Dakota Sandstone have been described as wet in several drill hole logs and as saturated at some locations (wells 198-2, 200-2, and 197-3) (DOE 1994a, 1994b). In addition, wells 202-2, 203-2, and 204-2, all completed in fractured mid- to lower-Mancos Shale just below shallow weathered subcrop, on the north boundary of the millsite, have yielded ground water readily during well development and sampling periods.

Packer tests conducted in the Mancos Shale on the millsite (coreholes 201-1, 202-1, and 203-1) showed a range in estimated hydraulic conductivity from 9.5×10^{-10} to 5.4×10^{-3} cm/s. The larger estimates of hydraulic conductivity were associated with fractured shale zones that generally occur in or just below the upper weathered portion of the shale but also may occur in isolated zones at depth. Packer tests performed in the Dakota Sandstone (corehole 204-1) on the millsite yielded a range in the estimated hydraulic conductivity from 1.0×10^{-9} to 2.1×10^{-5} cm/s. The geometric mean of the hydraulic conductivity for both the Mancos Shale and Dakota Sandstone is approximately 4×10^{-7} cm/s (Harding Lawson Associates [HLA] 1993). In addition, at and south of the millsite ground water analyzed for carbon-14 and tritium in the lower Dakota Sandstone has shown apparent ages of 22,000 to 29,000 years, whereas the underlying Burro Canyon aquifer ground water has been dated at approximately 3,800 to 5,000 years (DOE 1992a, 1994b). The difference in apparent ages between the Dakota Sandstone and Burro Canyon ground water suggest little-to-no hydraulic communication between these hydrogeologic units.

Flow, however small, in the Mancos Shale and Dakota Sandstone is predominately vertical, as indicated by the calculated vertical gradient between well sites 200-2 and 200-3. The calculated vertical gradient is 0.95 or nearly a unit gradient and implies gravity flow (downward vertical flow). Other vertical gradients calculated between wells completed in the upper flow system (31SW91-36 and 198-2) and wells completed in the upper Dakota and lower Dakota Sandstone (199-1 and 198-1, respectively) show values of 0.91 and 1.00, respectively (DOE 1994a). Some preferential flow probably occurs in fractures, fractured zones, and/or more conductive layers such as clean sandstones and coal seams.

Because of the overall low permeability of the Mancos Shale and Dakota Sandstone, ground-water flow in these units is considered minimal. Some recharge to the Mancos Shale and Dakota Sandstone probably occurs as leakage from the upper flow system, and/or from Montezuma Creek in areas where bedrock forms the creek bottom. Similarly, discharge from the Mancos Shale and Dakota Sandstone probably occurs as negligible leakage to Montezuma Creek and the Burro Canyon aquifer in places. A clear relationship between Montezuma Creek flows and Mancos Shale and Dakota Sandstone ground-water levels are not apparent because stream gains and losses are not consistent over the reach where these units' subcrop. In most instances, the upper flow system acts as an intermediate flow regime between surface water and the Mancos Shale and Dakota Sandstone.

During the baseline characterization project, ground water could not be collected from Dakota wells upgradient and downgradient from the millsite because of a poor yield. Since that characterization took place, two Dakota wells (wells 92-12 and 92-13) have been sampled for chemical analysis. During the 1993 Alternatives Analysis Project, ground-water samples were collected from Mancos Shale wells 202-2, 203-2, 204-2, and 200-3 and Dakota well 200-2 located on the millsite. Mancos Shale ground water is generally of the calcium-sulfate type and Dakota ground water is generally of the sodium plus potassium-bicarbonate type.

The results of metals analyses generally showed less than the EPA's contract laboratory program (CLP) contract required detection limits (CRDL) in the Mancos Shale ground water with low but detectable concentrations of arsenic, copper, cadmium, lead, and zinc in Dakota Sandstone ground water. Vanadium concentrations in the Mancos Shale were less than the CRDL with the exception of wells 200-3 and 202-2, which had concentrations of approximately 14 and 196 micrograms per liter (μg/L), respectively. Dakota wells 92-12 and 92-13 had vanadium concentrations of less than the CRDL and approximately 36 μg/L, respectively. Radiological analyses of Mancos Shale ground water generally showed Ra-226 and Ra-228 concentrations less than the laboratory reporting limits (LRL), and uranium concentrations less than 35 μg/L (except at 202-2, where the uranium concentration measured 1,290 μg/L). Radiological analysis samples collected for the baseline characterization generally showed that gross alpha, gross beta, Pb-210, Po-210, Ra-226, Ra-228, Th-230, and U-235 were not detected at or above LRLs for Dakota Sandstone ground water; relatively low concentrations of uranium, U-234, U-238, and Rn-222 were detected (DOE 1994b).

2.1.4.3 Burro Canyon Aquifer

The Burro Canyon aquifer is the main source of potable ground water in the region. The town of Monticello uses Burro Canyon well water for irrigation purposes, and during drought, as a source of potable water. The Burro Canyon aquifer also is tapped by several private wells in the area. Limited research indicates that many of the private wells are generally old (over 10 years and up to 40 years old), and have not been used for many years. Some wells, however, have been used within the last 10 years during periods of drought for domestic, irrigation and stock water supplies.

The Burro Canyon Formation outcrops approximately one mile east of the millsite in upper Montezuma Creek. Approximately 4,000-ft east of the millsite, the Dakota Sandstone has been eroded away and the upper ground-water flow system is in direct contact with the Burro Canyon Formation. The thickness of the Burro Canyon Formation is 114 ft at well 83-70, the only drillhole that has fully penetrated the Burro Canyon Formation on and in the vicinity of the MMTS. Well 83-70 is located approximately 600-ft east of the millsite. There, the upper 67 ft of the Burro Canyon Formation comprises fractured, generally poorly cemented sandstone. At the base of this sandstone is an 8-ft thick layer of interbedded clay (shale) and sandstone that in turns overlies a lower, 39-ft thick subunit of predominantly conglomeratic sandstone. Below the conglomeratic sandstone, the mudstones and shales of the Brushy Basin Member of the Morrison Formation restrict the downward migration of water.

The results of hydrogeologic investigations at and south of the millsite have found (1) an apparent weak hydraulic connection exists between the lower Dakota Sandstone and Burro Canyon Formation, thereby separating these strata into different hydrostratigraphic units; (2) using a strict definition of a confined aquifer as an aquifer that exhibits a piezometric head above the formation's upper contact, the Burro Canyon aquifer is unconfined west (upgradient) of the millsite, generally confined on the millsite, and semiconfined to unconfined downgradient of the millsite; (3) water levels between the lower Dakota Sandstone and Burro Canyon Aquifer are generally within a few feet of each other, but vary on which level is higher; and (4) the presence of a distinct confining bed is not obvious, indicating that low permeability sandstones of the lower Dakota Sandstone confines the Burro Canyon aquifer in places.

Potentiometric head in the Burro Canyon aquifer varies from approximately 70 ft below to 30 ft above the formation's upper contact (see Table 2.1-1). Upgradient Burro Canyon wells 92-02 and 92-04 exhibit unconfined conditions. Wells 92-06 (west of Highway 191), 104-5 and 197-2 (south of the millsite), 200-1 and 93-01 (southwest portion of the millsite), and 205 (northwest of the millsite), exhibit confined conditions. An accurate delineation between upgradient unconfined conditions, millsite confined conditions, and semi- or unconfined downgradient conditions have not been determined because of the limited number of wells completed in this formation.

Table 2.1-1. MMTS Area Burro Canyon Water Levels Relative to Top of Burro Canyon Formation.

Well Identification	Water-Level Position Recorded February 1994
92-02	-68
92-04	-50
92-06	11
92-10	7
104-5	6
197-2	30
200-1	10
205	18
93-01	6

At the site of the single Burro Canyon well downgradient of the millsite, well 92-10, the Burro Canyon Formation directly underlies alluvium. Water levels in well 92-10 are approximately 2 to 7 ft above the contact between the alluvium and weathered Burro Canyon Formation indicating confined conditions, yet, levels are also approximately 2 ft below alluvial water levels in adjacent well 92-09. Well 92-10 is the only Burro Canyon monitoring well in the study area that exhibits strong seasonal water-level fluctuations, which indicate hydraulic

connection to the overlying alluvial sediments. On the basis of this information, the Burro Canyon aquifer at this location is interpreted as semiconfined.

In cases where the piezometric head in the Burro Canyon aquifer lies above the Burro Canyon Formation contact, the presence of a confining bed is not obvious. South of the millsite some borings have intercepted a thin (1- to 3-ft thick) siltstone as the uppermost stratum in the Burro Canyon Formation. Where present, this siltstone may act as a confining unit. At and south of the millsite, the uppermost Burro Canyon has been described in places as silty or as a very fine-grained sandstone. However, a distinct lithologic confining unit between the Dakota Sandstone and Burro Canyon Formation is generally absent. In all locations, the lower Dakota Sandstone is of relatively low permeability compared to that of the Burro Canyon Formation. This low permeability is exhibited by low well yields and results of laboratory vertical conductivity tests of the core. Laboratory testing of the core has shown that the lower Dakota Sandstone exhibits permeabilities as much as five orders of magnitude less than that of upper Burro Canyon aquifer material (lower Dakota Sandstone in the range of 10^{-9} cm/s versus upper Burro Canyon Formation in the range of 10^{-5} to 10^{-4} cm/s [Advanced Terra Testing 1992]). This information suggests that well to moderately cemented sandstones of the lower Dakota Sandstone form the confining unit above the Burro Canyon aquifer.

The hydraulic characteristics of the Burro Canyon aquifer have been estimated from published literature of hydraulic tests as well as from tests conducted on the millsite as part of the MRAP. Avery reported values of hydraulic conductivity of 0.77 and 0.35 ft/day (2.7×10^{-4} to 1.2×10^{-4} cm/s, respectively) from pumping tests conducted in millsite-area AEC wells completed in the Dakota Sandstone and Burro Canyon Formation (Avery 1986). Associated storage coefficients were 1.4×10^{-5} and 1.0×10^{-5}, indicating confined conditions. Freethey and Cordy reported transmissivity values between 70 and 150 ft^2/day (6.5×10^3 and 1.4×10^5 square centimeters per day [cm^2/day], respectively) for the Dakota/Burro Canyon aquifer in the Monticello, Utah, area (Freethey and Cordy 1991). These authors also showed that the hydraulic conductivities for the Dakota/Burro Canyon aquifer had a narrow 95-percent confidence interval of approximately 0.18 to 0.5 ft/day (6.4×10^{-5} to 1.8×10^{-4} cm/s, respectively) for 60 laboratory analyses collected from outcrop and core in the study area of the upper Colorado River Basin in Wyoming, Colorado, Utah, Arizona, and New Mexico.

Pumping tests in the Burro Canyon Formation on the millsite were conducted in 1983 and 1984 using pumping well 83-70 and observation wells 83-71, 84-74, and 84-75. The results of the tests showed a range in transmissivity between 188 to 296 ft^2/day (1.7×10^5 to 2.7×10^5 cm^2/day, respectively), and a range in storativity between 3.9×10^{-4} to 0.015 (values indicate both confined and unconfined conditions, depending upon observation-well location) (DOE 1993d). Using an approximated saturated thickness of 100 ft for the Burro Canyon aquifer, the hydraulic conductivity is estimated to range between 1.88 to 2.96 ft/day (6.6×10^{-4} to 1.0×10^{-3} cm/s). Slug tests conducted in 1993 in four Burro Canyon wells (92-02, 92-04, 92-06, and 92-10), upgradient and downgradient of the millsite, resulted in estimated hydraulic conductivities ranging from approximately 0.85 to 2.6 ft/day (3.0×10^{-4} to 9.3×10^{-4} cm/s, respectively).

Vertical hydraulic conductivity laboratory analyses conducted on eight core samples collected as part of the 1992 baseline characterization showed Burro Canyon values ranged from 8.1×10^{-10} to 7.1×10^{-4} cm/s, with an average of approximately 1.2×10^{-4} cm/s. Porosity values ranged between approximately 15 and 24 percent, with an average of 18.5 percent (Advanced Terra Testing 1992).

Ground water in the Burro Canyon aquifer flows east in the vicinity of the millsite. Horizontal hydraulic gradients in the Burro Canyon aquifer are approximately 0.004, 0.006, and 0.01 for area's upgradient, on, and downgradient of the millsite, respectively (DOE 1994a).

The primary recharge zone for the Burro Canyon aquifer is in outcrop areas along the east margin of the Abajo Mountains. Regionally, discharge from the aquifer occurs across the Sage Plain (the broad, relatively flat region east of Monticello) in areas where canyons dissect the Burro Canyon Formation. Locally, the primary discharge paths from the aquifer occur by way of leakage into overlying alluvium and Montezuma Creek in the area upstream from the Vega Creek confluence, and by high evapotranspiration of ground water in areas where the Burro Canyon Formation forms cliff outcrops along the margin of Montezuma Canyon below the Vega Creek confluence. In the Monticello area, a secondary means of discharge of the Burro Canyon aquifer may occur by way of pumping withdrawals. The town of Monticello occasionally (in times of drought or otherwise high water demand) uses Burro Canyon aquifer ground water to irrigate public parks and school grounds.

Ground-water quality associated with the Burro Canyon aquifer is discussed in detail in the *Baseline Characterization Data Summary* (DOE 1994b) and summarized in Section 4.4 of this Work Plan.

2.1.4.4 Surface Water

The east flank of the Abajo Mountains is drained by two principal watersheds, North Creek and South Creek. These two streams, along with an unnamed tributary to the south that is generally dry, join west of U.S. Highway 191 to form Montezuma Creek. Other smaller creeks also drain the east slope of the Abajo Mountains, but they circumvent the tailings' area and join Montezuma Creek downstream of the millsite. In 1985, Monticello Reservoir (Loyd's Lake) was constructed on South Creek, approximately one mile upstream from the millsite.

The original Montezuma Creek stream channel was modified during the construction of the U.S. Highway 191 embankment that crosses Montezuma Creek just west of the MMTS. In addition, the channel was significantly altered by activities related to the milling process and subsequent reclamation work. In the eastern portion of the millsite, the stream channel was relocated to the south and lined with riprap. Because of this realignment, the apparent axis of the upper flow system is geographically offset from the present location of Montezuma Creek in the eastern portion of the millsite. In this portion of the millsite fluvial sediments are present along the stream's former alignment and Montezuma Creek currently flows over the Dakota Sandstone. The creek and alluvial sediments characteristic of the upper flow system

are reunited downstream of the millsite. At the eastern boundary of the millsite a drop structure was built to return the altered stream bed to its original base level and to prevent headward erosion of the creek into the tailings area.

The U.S. Geological Survey (USGS) gauges flow of South Creek immediately upstream from the reservoir. USGS records indicate that maximum discharges occur in the spring and early summer months and that low- to no-flow conditions prevail in the late summer, fall, and winter months (DOE 1990b). In the project area, base flow in Montezuma Creek is maintained year-round by ground-water discharge from the upper ground-water flow system and by releases (mostly leakage) from Monticello Reservoir.

Stream-flow measurements for Montezuma Creek for the period between December 1992 and October 1994, are shown in Table 2.1-2, and corresponding stream gains and losses between established stations (see Plate 2-2) are summarized in Table 2.1-3. As these tables illustrate, flows vary considerably, and conditions of gain or loss are not consistent for some reaches for different measuring times. Montezuma Creek and the upper flow system have a dynamic relationship dependent upon numerous factors including precipitation events, irrigation practices, and upstream releases from Loyd's Lake Reservoir. A general evaluation of base flow conditions (flow conditions in the fall when natural or external sources are generally at a minimum and influence of ground water conditions are more easily recognized) for September 1993 and October 1994 shows greater flows in 1993 than in 1994, and inconsistencies continue to exist for gains or losses between some stations. In general, Montezuma Creek is slightly losing immediately upstream from the millsite, gaining on the west half of the millsite, losing across the east portion of the millsite, either gaining or losing immediately downstream from the millsite (from stations SW92–05 to SW92–06), primarily gaining in the narrow portion of lower Montezuma Creek to station SW92–08, losing from station SW92–08 to SW92–09 just downstream from the Vega Creek confluence area, and generally gaining in Montezuma Canyon (SW92–09 to the Montezuma Canyon surface water station). Further analysis of current and future data is needed to more clearly understand the interconnectedness between the stream and the upper flow system as well as influences from bedrock hydrostratigraphic units and other natural or external sources (see Section 4.8).

In 1989, the U.S. Army Corps of Engineers conducted a wetland's assessment of Montezuma Creek from U.S. Highway 191 to its confluence with Vega Creek. On the basis of this assessment, wetlands exist along Montezuma Creek in a sinuous band that varies in width from 30 to 45 ft on either side of the center line of the stream. Results of the assessment provide a general indication of the distribution of wetlands along the creek.

Tributaries to Montezuma Creek upstream of the Verdure Creek confluence flow intermittently. These tributaries include the North Drainage (also known as Steel's Draw) on the north side of the millsite, the unnamed draw that intersects upper Montezuma Creek from the south near surface water station SW92–06, the unnamed draw that intersects lower Montezuma Creek from the north near surface water station SW92–08, Vega Creek, and all tributaries between Vega Creek and Verdure Creek, including Halfway Hollow. Flow occurs in these tributaries during spring snowmelt and during and after some precipitation events.

Table 2.1-2. Montezuma Creek Measured Flow Data

Montezuma Creek Station	Cubic Feet per Second												
	12/8/92	3/11/93	5/18/93	6/15/93	8/5/93	8/25/93	9/27/93	5/9/94[3]	5/26/94[3]	6/28/94[3,5]	7/25/94	8/29/94	10/4/94[3,8]
SW92-01	0.11	0.42	0.85	6.03	7.36	0.54	0.46	0.27	0.30	0.16	0.16	0.12	0.11
SW92-02	0.38	0.69	27.82	8.42	0.69	0.05	IF	0.31-0.57	0.38-0.28	0.17-0.33	0.03	0.05	0.07
SW92-03	Dry	0.72	16.17	13.55	6.58	0.29	0.42	0.38	0.48	0.23-0.25	0.10	0.14	0.26[9]
SW94-02	-	-	-	-	-	-	-	1.02[4]	0.66[4]	0.34	0.14	0.35	0.23
SW92-04	Frozen	3.10	29.15	26.07	-	1.76	0.20	0.78	1.23	0.51-0.39	0.17	0.29	0.28
SW92-05	Frozen	2.02	20.52	25.53	-	1.49	0.88	1.05	1.25-1.35	0.40	0.42	0.33	0.21
W-4	0.91	1.77	26.34	20.33	0.43	2.8[2]	1.37	0.83	0.22	0.24[4,6]	IF	0.31	0.48
SW92-06	1.47	2.67	9.71	8.49	1.11	4.01	0.40	0.98	0.79	0.50	.003?	0.26	0.31[4]
Sorenson	2.25	2.44	16.05	16.45	1.26	3.49	1.15	1.26	0.89	0.45	0.27	0.45	0.57
SW92-07	2.67	2.56	20.36	16.09	1.61	1.55	1.66	1.22	0.90	0.46-0.48	0.14	0.48	0.50
SW92-08	3.34	3.56	21.39	25.00	2.02	3.45	3.46	1.17	0.83	0.53-0.54	0.022?	0.53 0.53D	0.56
SW92-09	3.42	3.28	19.71	15.95	1.13	2.81	2.80	1.35	0.68	0.53	0.035	0.47	0.58
SW94-01	-	-	-	-	-	-	-	1.25	0.78	0.49	0.07	NM	0.59
Montezuma Canyon	-	29.37[1]	33.46	23.07	1.55	1.73	4.30	1.62	1.11	0.04	NF	21.45[7]	1.48

[1] Measured below Verdure Creek confluence. [2] Heavy precipitation in the area. [3] Irrigation of fields north of creek near station W-4 occurring during measurement event, [4] Seep observed on stream bank near this location. [5] Minor diversion or flow of water observed in Hall's Ditch. [6] Diversion of water from Montezuma Creek at drop structure at east boundary of millsite to irrigate field south of creek and east of millsite. [7] Equipment failure, velocity visually estimated, creek was full. [8] Pump operating near well 92-08. 9 Minor flow occurring from North Drainage on millsite. - = not measured because station was not established at time of measurement, IF = insufficient flow to make measurement, D = duplicate measurement, NF = no flow stagnant water, NM = not measured.
6/94 flows all less than 0.6 cfs
7/94 all flows less than 0.45 cfs, no flow at W-4 and M. Canyon, trace flow at SW92-06
8/94 all flows less than 0.55 cfs except M. Canyon which was visually estimated (creek was full) due to equipment failure
10/94 all flows less than 0.60 cfs except M. Canyon which was 1.48 cfs

Table 2.1-3. Summary of Montezuma Creek Loss and Gain Between Stream Flow Measurement Stations

Montezuma Creek Segment	12/8/92	3/11/93	5/18/93	6/15/93	8/5/93	8/25/93	9/27/93	5/9/94	5/26/94	6/28/94	7/25/94	8/29/94	10/4/94
SW92-01 & SW92-02 to SW92-03	L-	L-	L++	L-	L++	L+	L-	L+	L-	L-	L-	S	G-
SW92-03 to SW94-02[1]	-	-	-	-	-	-	-	G+	G+	G-	G-	G +	S
SW94-02 to SW92-04	-	-	-	-	-	-	-	L+	G+	G+,S	S	S (L-)	S
SW92-03 to SW92-04	-	G++	G++	G++	-	G++	L+	(G)+	(G)+	(G)+	(G)-	(S)	(S)
SW92-04 to SW92-05	-	L++	L++	L-	-	L+	G+	G+	S	L+,S	G+	S	L-
SW92-05 to W-4	-	L+	G++	L++	-	G++	G+	L+	L++	L+	L+	S	G+
W-4 to SW92-06	G	G+	L ++	L++	G+	G++	L+	G+	G+	G+	S	S	L+
SW92-06 to Sorenson	G	L+	G++	G++	G+	L+	G+	G+	G-	S	G+	G+	G+
Sorenson to SW92-07	G	G+	G++	L+	G+	L+	G+	S	S	S	L+	S	L-
SW92-07 to SW92-08	G-	G++	G++	G++	G+	G++	G++	S	L-	G-,S	L+	S	G-
SW92-08 to SW92-09	G	L+	L+	L++	L+	L+	L+	G+	L+	S	S	S	S
SW92-09 to SW94-01	-	-	-	-	-	-	-	L-	G+	S	S	-	S
SW92-09 to Montezuma Canyon	-	G++	G++	G++	G+	L++	G++	G+	G+	L+	S	G+	G+

[1] Slade Spring exists in north stream bank between stations SW92-03 and SW94-02, flow is approximately 40 gpm or 0.09 cfs.
S = static = less than or equal to 0.05 cfs loss, L- = less than or equal to 0.10 cfs loss, L+ = greater than 0.10 cfs loss, L++ = greater than or equal to 1.0 cfs loss.
S = static = less than or equal to 0.05 cfs gain, G- = less than or equal to 0.10 cfs gain, G+ = greater than 0.10 cfs gain, G++ = greater than or equal to 1.0 cfs gain.
- = not measured.

Several seeps and/or springs have been located in the area (see Plate 2-2). Seeps and springs that have shown persistent flow in the last year (1994) occur on the north slope (south-facing slope) of upper Montezuma Creek north and east of the millsite. Where present, these seeps and springs generally occur in drainages, at or near the exposed geologic contact between the Quaternary alluvium and the Mancos Shale, and in areas where the Mancos Shale has been exposed by excavation activities. Typically seeps and springs exhibit diffuse flow and are characterized by wet soil or rock over a modestly large surface area, say 20 ft by 5 ft or larger, with a smaller portion of that area showing small amounts of actual flow or rills of water. The amount of seep discharge is dependent on seasonal climatic conditions, distinct precipitation events, and irrigation schedules. Some seeps may also be the result of underground leaking municipal water lines or sewage lines, particularly in the area north of the millsite.

Slade Spring, located on the north stream bank of Montezuma Creek between surface-water stations SW92–03 and SW94–02 just south of the BLM compound, flows at approximately 40 gallons per minute (gpm). The focused discharge and the presence of chlorine in an initial water samples from this spring support the hypothesis that this water originated from a municipal source. More recent investigations, however, resulted in stopping a pipeline leak on the millsite, excavating the area around the spring, and retesting the spring water for chlorine. Chlorine was not detected and the spring continues to flow. Excavation of the spring area near the creek showed that flow was occurring in a well-developed, sinuous underground channel or washout, with no evidence of man-made piping. There is still the possibility, however, that the origin of this spring is related to municipal water lines located in or near the northwest portion of the millsite property.

In 1993, millsite excavation activities associated with the remediation program exposed Mancos Shale on the north hillslope area along the northwest and northeast portions of the millsite property and similar activities have exposed the shale on the southeastern portion of the millsite. Seepage from the northern exposures is common, but is laterally discontinuous and generally of low volume (approximately less than 5 gpm per 20-ft exposure length). At the southeastern exposure, ground-water seepage emanates from bedding planes of the shale, and occasionally causes some minor surface ponding near the foot of the hillslope. Seepage is generally diffuse in that the shale has a wet appearance without any well-defined flow channels.

Reconnaissance conducted in the spring of 1994 along the north hillslope north of the millsite boundary delineated several seepage areas near the Quaternary/Mancos Shale contact (North Drainage, Pehrson 1, and Pehrson 2 seeps). The origin of the Clay Hill seep, located between Clay Hill Drive and the millsite boundary, is not clear because of limited access, but flow appears to be emanating from surficial thin soil on top of the Mancos Shale. Another seep/spring, the Goodknight Spring, occurs on the south-facing slope in the northwestern portion of the millsite. Here, an old, tufa-encrusted culvert emits approximately 0.5 gpm from the hillside.

Adams Spring and Cabin Spring were discovered during the Summer of 1995. The low-flowing (less than 1-2 gpm) Cabin Spring is located adjacent to an old "cabin" on the south side of Montezuma Creek across from the North Creek Diversion tributary. The spring generally occurs in a concentrated area or "channel;" however, the area is heavily overgrown with thick brush and flow cannot be measured. The actual origin of the spring is above the cabin on South slope of the Canyon — in the Burro Canyon Formation. Adams Spring is located immediately north of Clay Hill Drive approximately 2200 ft east of the millsite. This spring is characterized by low diffuse flow over a moderately-sized area on the hill slope.

Some seepage has been observed on the banks of upper and lower Montezuma Creek in places, and seeps also occur south of the Vega Creek confluence in Montezuma Canyon associated with the sandstone units within the Saltwash member of the Morrison Formation.

Overland flow (runoff) of water associated with precipitation events enters the project area from the north and south hillslopes along the Montezuma Creek valley. Along the millsite boundary, the north hillslope is drained by one principal tributary that heads in the town of Monticello. This watershed, known as the North Drainage (or Steel's Draw), has a total area of about 65 acres and is fed by springs and seeps that originate near the contact between the Quaternary pediment gravels and the Mancos Shale. In 1985, a diversion ditch was constructed along the northern perimeter of the site to collect storm water from this drainage. Water flowing into the diversion ditch is transmitted to one of two catch basins — one in the north-central portion of the millsite and the other at the northeast corner of the millsite. Both of these catch basins feed buried pipes that convey the water to outfalls along Montezuma Creek. A pond forms at the intake to the west catch basin near the Carbonate and Vanadium Tailings Piles because the basin's intake is set too high in elevation. The pond acts as a source for infiltration and recharge to the upper ground-water flow system.

The south hillslope is drained by two small watersheds that enter the site southwest of the Acid Tailings Pile. The total basin area of each of the drainages is 10 to 15 acres. Both of these watersheds are typically dry. An abandoned diversion ditch is present south of the Acid Tailings Pile and would probably divert any large amounts of surface flow that may occur in that area.

Surface-water quality at and in the vicinity of the MMTS is discussed in detail in the *Baseline Characterization Data Summary* (DOE 1994b) and summarized in Section 4.4.3.3 of this Work Plan.

2.1.4.5 Summary

The hydrostratigraphic units underlying upper and lower Montezuma Creek, from youngest to oldest, are an upper aquifer consisting of unconsolidated alluvial material and weathered bedrock, referred to as the upper flow system; an aquitard consisting of Mancos Shale and Dakota Sandstone; and a lower aquifer consisting of the Burro Canyon Formation. The ranges in thicknesses of the upper flow system, aquitard, and Burro Canyon Formation are approximately 0 to 30 ft, 0 to 130 ft, and 115 to 150 ft, respectively.

The upper flow system consists of heterogeneous alluvial material (clay, silt, sand, and gravel) and, in places, weathered (fractured and more friable) bedrock. The upper flow system is generally bound by the hillslopes and walls of upper and lower Montezuma Canyon. The unit pinches out, coalesces with thin colluvium, and/or is generally unsaturated or of thin saturated thickness in these areas. Ground water in the upper flow system generally flows eastward within OU III; however, potentiometric contour maps indicate that flow on the north and south flanks of the Montezuma Creek valley is from the northwest and southwest, respectively. Saturated thicknesses of the upper flow system range from approximately 2 to 25 ft, but generally are less than 15 ft. Surficial recharges to the upper flow system are estimated to be approximately 1×10^{-9} to 1×10^{-7} cm/s (DOE 1994a). Well hydrographs indicate that some wells, particularly those located in areas with thin alluvium, show occasional sporadic water-level fluctuations, probably because of relatively rapid recharge preceding a recent precipitation event. Horizontal hydraulic gradients range from 0.01 (central valley) to 0.1 (valley flanks). Where measured, vertical gradients between the upper flow system and bedrock ground water are downward and range between 0.29 and 1.0 (DOE 1994a). The hydraulic conductivity of the upper flow system, based on pumping and slug tests to date, ranges from 7.4×10^{-4} to 1.8×10^{-1} cm/s.

The Mancos Shale and Dakota Sandstone Formations are generally perceived to act as an aquitard. Because the Mancos Shale is virtually absent from the central portion of upper Montezuma Creek, the Dakota Sandstone is the primary hydrostratigraphic unit that separates the upper flow system from the Burro Canyon aquifer. The unit comprises interbedded siltstones, sandstones, shales, and some coal beds. The few wells that are completed in the Dakota Sandstone produce small amounts of water — in some cases not enough water to collect samples. Vertical hydraulic gradients from the upper flow system (wells 198-1 and 198-2) or from the overlying Mancos Shale (well cluster 200) to the Dakota Sandstone has been calculated at approximately 1.0 (i.e., flow occurs by gravity drainage). Hydraulic conductivities of the Mancos Shale and the Dakota Sandstone, as estimated by packer tests, range from 9.5×10^{-10} to 5.4×10^{-3} cm/s (fractured shale) and 1.0×10^{-9} to 2.1×10^{-5} cm/s, respectively. The geometric mean of the hydraulic conductivity for each of these units is approximately 4×10^{-7} cm/s (HLA 1993).

The Burro Canyon Formation consists mostly of sandstone with some interbeds of pebble conglomerate and green shale or siltstone. The formation is about 115-ft thick near the millsite, and may attain thicknesses up to about 150-ft thick in the Monticello area (Craig 1982). The Burro Canyon Formation is unconfined west of the MMTS, generally confined on the millsite, and semiconfined to unconfined downgradient of the millsite. On the basis of information to date, ground-water flow in the Burro Canyon aquifer is due east with hydraulic gradients of 0.004, 0.006, and 0.01 for the areas upgradient of the millsite, on the millsite, and downgradient of the millsite, respectively. Published reports (Avery 1986; Freethey and Cordy 1991) and pumping test results from the MMTS show the hydraulic conductivity of the Burro Canyon aquifer to range from 6.4×10^{-5} to 1.0×10^{-3} cm/s, with a mean of about 5×10^{-4} cm/s. Laboratory vertical conductivity tests conducted on Burro Canyon core showed values ranging from 8.1×10^{-10} to 7.1×10^{-4} cm/s and an average of approximately 1.2×10^{-4} cm/s (Advanced Terra Testing 1992).

The hydraulic connection between the upper flow system and the Burro Canyon aquifer is restricted where the aquitard exists. This is supported by field observations of relative well recovery, documented hydraulic conductivity estimates (field and laboratory), differences in ground-water chemistry, radiological age-dating analyses, and general evidence of no contamination in the Burro Canyon aquifer. Differences in hydraulic head between these units, however, do indicate that a downward hydraulic gradient exists.

Surface water on and in the vicinity of the MMTS includes Montezuma Creek and a number of seeps and/or springs. Montezuma Creek, a relatively low-discharge perennial stream, forms at the junction of North and South Creeks that head in the Abajo Mountains, located several miles to the west, and flows east through the MMTS and then south through Montezuma Canyon. Flow measurements collected on Montezuma Creek within the MMTS show flow ranges from less than 1.0 ft^3/s during base flow to almost 30 ft^3/s during spring runoff. The interconnectedness between Montezuma Creek and the underlying upper flow system and bedrock unit is not fully understood. Stream flow data collected to date indicate that stream gains and losses are generally inconsistent from station to station for different measurement events, but some general trends have been observed. Montezuma Creek is slightly losing immediately upstream from the millsite, gaining on the west half of the millsite, losing across the east portion of the millsite, either gaining or losing immediately downstream from the millsite (from stations SW92-05 to SW92-06), primarily gaining in the narrow portion of lower Montezuma Creek to station SW92-08, losing from station SW92-08 to SW92-09 just downstream from the Vega Creek confluence area, and generally gaining in Montezuma Canyon (to the Montezuma Canyon surface water station).

Seeps and/or springs in the area, where present, generally occur in drainages, at the geologic contact between the Quaternary alluvium and the Mancos Shale, and in areas where the Mancos Shale has recently been exposed by excavation activities. Discharge from each of these seeps is generally small, but may vary depending on seasonal climates, distinct precipitation events, and/or irrigation schedules. One sizeable (40 gpm) spring flows into upper Montezuma Creek in the western portion of the millsite.

Overland flow of storm water runoff entering the MMTS project area originates from the north and south hillslopes along the Montezuma Creek valley. Along the millsite boundary, the north hillslope is drained by one principal tributary that heads in the town of Monticello. This watershed has a total area of about 65 acres. The south hillslope is drained by two small watersheds that enter the site southwest of the Acid Tailings Pile. The total basin area of each of the drainages is 10 to 15 acres. Both of these watersheds are typically dry.

2.2 Historical Setting

The uranium and vanadium mill at Monticello was one of the earliest to operate on the Colorado Plateau and was at the forefront of developments in uranium-milling technology throughout its period of operation. The Monticello mill was one of the first two plants in the United States to use the acid leach resin-in-pulp (RIP) process and was the first to employ the carbonate leach RIP process. Mill operations at Monticello were also a focal point of early

environmental concerns. After the mill closed in 1960, it was the first inactive site to undergo extensive tailings stabilization.

This synopsis of the history of the Monticello mill is intended to provide general background information for understanding the environmental problems posed by the mill both during its operation and after its closure.

2.2.1 Mill Ownership

2.2.1.1 Vanadium Corporation of American Operations, 1941 to 1946

In late 1940, the Vanadium Corporation of America (VCA) opened a vanadium ore-buying station in Monticello to stimulate vanadium mining in the region. Within a short time, ore production increased enough to justify construction of a vanadium mill, and in September 1941, the War Production Board approved the proposal submitted by VCA for mill construction. Funding for construction was provided by the U.S. Government through the Defense Plant Corporation. The Metals Reserve Company assumed operation of the ore-buying station in April 1942, while the VCA operated the mill. The first vanadium was produced at the new mill on August 24, 1942. In 1943, VCA began producing a uranium-vanadium sludge for the Manhattan Engineer District, which had recently initiated a program to obtain domestic uranium. The mill closed in February 1944.

The VCA reopened the mill from 1945 to 1946 under lease from the Defense Plant Corporation and purchased stockpiled ore from the Metals Reserve Company. During this time, the VCA produced a uranium-vanadium sludge which it sold to the Manhattan Engineer District.

2.2.1.2 Atomic Energy Commission Operations, 1948 to 1962

The U.S. Atomic Energy Commission (AEC) bought the Monticello millsite from the War Assets Administration in 1948. The American Smelting and Refining Company acted as the ore-buying agent for the AEC. The Galigher Company was hired to design and operate a uranium mill at the site. In February 1956, Lucius Pitkin, Inc. replaced American Smelting and Refining Company as ore-buying agent, and in April 1956, the National Lead Company assumed operation of the mill. Shortly thereafter, the National Lead Company also took over ore weighing, sampling and stockpiling activities, while Lucius Pitkin, Inc., continued to handle administrative activities associated with ore purchased contract, assaying, and settlements. The mill closed in January 1960, but the ore-buying station remained open until March 31, 1962.

2.2.2 Milling Processes

2.2.2.1 Vanadium Corporation of America Salt Roast Process

During VCA operations at the Monticello mill, a salt roast process was used to convert vanadium minerals to soluble form. However, the high lime content of the carnotite ore processed at the mill presented metallurgic problems. The calcium carbonate caused excessive slagging, and the calcium, liberated by roasting, formed insoluble vanadium compounds. Consequently, pyrite was added to cause some of the calcium to form calcium sulfate. The hot ore was quenched in a solution of sodium carbonate, at which point, most of the vanadium dissolved, and calcium remained as calcium chlorate precipitated as calcium carbonate. After successive washings, the sands were transferred to tailings. Precipitation of vanadium pentoxide (V_2O_5) from the pregnant liquor was induced by the addition of sulfuric acid. The precipitate was washed to remove sodium chloride and sodium sulfate, and the wash water was discharged to the nearby creek.

2.2.2.2 Atomic Energy Commission Processes

Ores received at the AEC ore-buying station and processed at the mill came from a wide geographic area and had a broad spectrum of metallurgic properties that affected the milling processes. Tests on the ores for process amenability were conducted by the Monticello Plant, by the U.S. Bureau of Mines in Salt Lake City, and by the AEC Pilot Plant in Grand Junction.

A number of milling processes were used at Monticello during the 11 years of AEC operation. These included raw ore carbonate leach, low-temperature roast/hot carbonate leach, and salt roast/hot carbonate leach up to 1955; acid leach RIP and raw ore carbonate leach from 1955 to 1958; and a carbonate pressure leach RIP process from August 1958 to mill closure in 1960. Three of the AEC processes used at the Monticello mill are summarized below.

2.2.2.3 Salt Roast/Carbonate Leach Process

Until 1955, vanadium was recovered with uranium. After being crushed, the ore was mixed with sodium chloride (common salt), 6 to 9 percent by weight, and roasted at temperatures near 850° C. The hot ore was quenched in a sodium carbonate solution, ground to natural grain size, and passed through a series of agitators and thickeners to dissolve the uranium and vanadium.

Sodium uranyl vanadate (yellowcake) was precipitated from solution by adding sulfuric acid to a pH of 6 and heating. Precipitation was considered complete when the filtrate contained less than 10 ppm U_3O_8. The filtrate was further acidified by the addition of sulfuric acid to pH 2.5 to precipitate vanadium oxide (red cake). The dried yellowcake was further refined by adding chloride, sodium carbonate and sawdust, and then fusing the substance in a furnace to produce uranium oxide (black cake). The vanadium and other impurities were eliminated by washing, and the wash solution was further treated to recover vanadium.

2.2.2.4 Acid Leach RIP Process

In 1955, the salt roast process and vanadium recovery were discontinued in order to improve uranium extraction. In November 1955, an acid leach RIP plant began operation. The previous carbonate leach plant was retained so that the mill could run two circuits simultaneously. Testing of ores for amenability had been conducted previously.

After being crushed and ground, the ore was mixed with sulfuric acid and manganese dioxide (oxidant) and passed through a series of eight agitators. Water for the leach circuit was recycled from the tailings pond overflow. The leached ore was passed through a series of classifiers to separate the sand and slime fractions. Sands were passed to the tailings pond, and slimes containing dissolved uranium were passed through a series of banks with screen eluted with a sodium nitrate solution acidified with sulfuric acid. Calcium hydroxide was added to the pregnant eluate to raise the pH to 3.4, whereupon the white cake, consisting mostly of calcium sulfate (gypsum), was precipitated. The white cake was recycled through the leaching circuit, and the filtrate was advanced to the second stage of precipitation, where yellowcake was produced by the addition of magnesium oxide to neutralize the filtrate.

The acid tailings were combined with the tailings from the carbonate plant to obtain partial neutralization. The combined tailings were then treated with calcium hydroxide to achieve complete neutralization and to flocculate the pulp, after which they were pumped to the tailings pond. About 130 gallons per minute of pond overflow was recycled through the leach circuit, while 180 gallons per minute was discharged to Montezuma Creek. Combined capacity at this time for the acid leach RIP and alkaline leach plants was about 600 tons of ore per day.

2.2.2.5 Carbonate Leach RIP Process

Conversion of the acid leach RIP plant to a carbonate leach RIP plant began in June 1958. The new plant began processing ore on August 8, 1958 at a capacity of 150 tons per day. Pilot plant studies used ore from the Monticello stockpiles. The resin was eluted with a sodium chloride solution. Precipitation of yellowcake was induced by the addition of sulfuric acid; neutralization with magnesium oxide followed.

Neither a flow sheet nor a reference, describing the carbonate pressure leach RIP process, has been located. However, the process used at Monticello is known to have been similar to the process later used at the uranium mill in Moab, Utah. There, the ore was ground to -65 mesh in a solution of sodium carbonate-bicarbonate. The pulp was then thickened to about 50 percent solids and subjected to pressure leaching with mechanical agitation in steam-heated autoclaves. After cooling, the leached pulp was passed through a sand-slime separation circuit. The uranium-bearing solution and slimes were then passed through the RIP circuit.

2.2.3 Relation of Tailings Piles and Milling Process

Prior to the installation of the acid leach RIP plant in 1955, tailings were discharged to two areas referred to as the Carbonate Pile and the Vanadium Pile. The Carbonate Pile is believed to be the oldest of the tailings piles; it received tailings from the AEC salt roast/carbonate leach process. The Vanadium Pile apparently obtains its name from the fact that vanadium concentrations are higher in this pile than in the other tailings piles. However, the origin of these higher concentrations is unknown because of the uncertainty regarding the date of the pile's construction and its exact relation to the milling processes in use prior to start-up of the acid leach RIP plant.

There is evidence that the Carbonate and Vanadium Piles were operated simultaneously in the 1951 and 1952 according to old records. The Carbonate Pile seems to equate with the "sand pond" and "old tailings pond" and the Vanadium Pile with the "settling pond" and "clarifier pond".

The salt roast performed for vanadium recovery was discontinued on June 1955. Vanadium precipitation on the circuit was continued, but the precipitated vanadium was passed to the "high vanadium tailing pond storage." This practice suggests that the Vanadium Pile may have been used to stockpile high-vanadium tailings for a short period of time following the cessation of vanadium recovery, although a resident manager of the mill at the time has no recollection of a separate stockpiling. It is certain, however, that the Vanadium Pile was not constructed for this purpose. The volume of tailings was too great in 1955 to have been produced by a plant that processed no more than about 100 to 120 tons of ore per day.

Because the acid leach RIP process required more water, a third pond was constructed South of Montezuma Creek to accommodate the added volume of discharge. This pond, referred to as the Acid Pile, contains the combined tailings, produced in 1955 and 1956 from the acid leach RIP and carbonate leach circuits.

After construction of the Acid Pond, it soon became apparent that a larger tailings pond would be required. Additional land, some of which had already been damaged by mill releases, was purchased east of the AEC property, and a new pond was constructed to retain a projected 578 acre-feet of tailings. This pond, the East Pile, received tailings from 1956 to 1960 when the mill closed.

2.2.4 Environmental Problems Associated with Mill Operations

2.2.4.1 Air Pollution

Prior to 1955, the environmental problems receiving attention at the Monticello mill came from the salt roast procedure used to enhance the vanadium recovery. Large quantities of dust, chlorine, and hydrogen chloride gas produced in this step of the mill flow sheet were exhausted through the roaster stack. Annual losses were estimated at 14,000 lb. V_2O_5 and more than 3000 lb. U_3O_8. Local residents complained about corrosion of wire fences,

clotheslines, galvanized roof, etc.; these complaints were verified by The Galigher Company. Stack releases largely disappeared when vanadium recovery was discontinued in 1955.

2.2.4.2 Water Pollution

Liquid effluent from the salt roast/carbonate leach plant, which contained substantial concentrations of chloride, sulfate, carbonate, bicarbonate, sodium, and other dissolved species, was released into Montezuma Creek. Elimination of effluent releases to Montezuma Creek became a goal in the subsequent design of tailings ponds and in research on milling processes. The Acid Pond was lined with 6 inches of compacted bentonite in an attempt to prevent seepage. Water from this pond was partly recycled to the acid plant. About 3500 gallons of barren elute (extract) were bled from the elution cycle daily to prevent resin poisoning. However, this solution contained high concentrations of nitrate and could neither be released into Montezuma Creek nor be recycled. Instead, it was disposed of in separate ponds and allowed to evaporate.

A water-sampling program began in March 1956 and continued through March 1959. The data acquired in the survey indicated that even with the East Pond, discharge of salts exceeded Utah water quality standards. In particular, when the carbonate leach RIP plant began operation, the pH values and concentrations of total dissolved solids, carbonate, bicarbonate, sodium, and chloride increased to levels above those observed during operation of the acid plant.

Emphasis shifted toward radiologic aspects of uranium milling in 1957 when the AEC released the "Standards of Protection Against Radiation" as 10 CFR 20. Included were standards for exposure of individuals to radiation and maximum permissible concentrations of radionuclides in water and air. Part 20 applied specifically to AEC licensees, so the Monticello mill was not legally subject to these standards. However, a directive was issued to achieve compliance at Monticello in order to provide a model for private mills. The program developed to reach compliance also included approval of sampling and analysis methods and development of controls for disposing of hazardous substances.

Release of radium-226 was of special concern. As early as 1950, it was recognized that radium levels in water and stream sediments were increasing as a result of uranium mill operations. In 1955, the flow in Montezuma Creek below the Monticello mill was noted to consist mostly of overflow and seepage from the tailings ponds. Soluble radium in the mill effluent was measured at 81 pCi/L. The radium-226 balance in the Monticello acid leach RIP plant was examined to determine what fraction was dissolved in the milling process and the ultimate disposition of radium through the various chemical separations. It was found that only about three percent of the radium in the ore was dissolved in the leach circuit. Of this amount, 10 percent precipitated with yellowcake. Most of the remainder of the dissolved radium was removed upon neutralization of the tailings in the tailings treatment step. Ultimately only 0.03 percent of the radium fed to process entered Montezuma Creek as solute. Soluble radium activity in Montezuma Creek was found to be 160 pCi/L; the maximum permissible concentration was 4 pCi/L above natural background. It was also recognized that

the suspended solids contained considerable radium activity, and that dry tailings were being washed into the creek.

A number of studies were subsequently conducted to determine methods for removing the small amount of dissolved radium. Barium sulfate was found to be the most effective compound for removing radium from tailings solutions. A test circuit was set up at Monticello to determine the feasibility of the treatment on a plant scale. Significant reductions of radium-226 were achieved, although the average concentration was still above 4 pCi/L. A second test circuit included iron sulfate heptahydrate ($FeSO_4 \cdot 7\ H_20$) as treatment to flocculate suspended solids; this brought dissolved radium concentrations to within acceptable levels.

2.2.5 Early Cleanup Activities

During milling operations, the tailings were normally moist so that erosion by wind was minimal. Within a year after shutdown, the tailings dams and surfaces of the piles dried out, and tailings sand started migrating as dunes. Erosion by water also became a problem.

In Summer 1961, the Atomic Energy Commission began to regrade, stabilize, and vegetate the piles. This work was initiated on the East Pile because, being the largest pile, it presented the greatest potential for wind erosion and migration of tailings off site. At the onset, a small pond still existed in the lowest part of the East Pile, and it was drained to the extent possible.

Slimes retained considerable moisture, even in "dry" parts of the pile, and many areas would not support heavy equipment. To overcome this obstacle, tailings sand was hauled from the other three piles and spread over the surface. These tailings mixed with the fluid slimes to provide a stable surface over which cover material could be spread. The depth of sand fill reached as much as 6 ft in places but averaged 3 or 4 ft. After the grading was completed, 8 to 12 in. of fill dirt and rock, excavated nearby, were spread over the tops and sides of the piles. Topsoil was added to the tops of the piles, fertilized, and a variety of native grasses were planted.

The mill facilities were dismantled concurrently. Equipment and scrap were sold to private firms, and unsold scrap material was buried or burned. Trenches were excavated near the Carbonate Pile, and scrap was buried under several feet of tailings. These tailings were covered with rock and soil and seeded in the same way as the piles.

Within a few years, it was evident that erosion problems were under control. Data suggested that dissolved and particulate radium concentrations in Montezuma Creek were diminishing. A radiologic survey of the site conducted in May 1965 concluded that exposure rates on the piles were slightly above background but did not result in a dose that exceeded the Federal Radiation Council Guide limit of 0.5 rem/yr for the general public. This was not true of the ore-storage areas. These areas had been cleared of visible ore fragments when the mill closed, but ore apparently remained buried in the soil. During the summer of 1965, topsoil to a depth of 6 to 12 inches was removed from the ore-storage areas. Photographs archived at the Grand Junction Office suggest that the contaminated soil was used as fill material to partially bury the

mill foundations. A subsequent radiologic survey of the ore-storage areas was conducted by the AEC Grand Junction Office, results of which indicated that a radiation hazard no longer existed according to standards in effect at the time.

In 1972, the AEC requested additional radiation surveys of the South stockpile area and the ore-buying station. These surveys indicated that considerable contamination remained and recommendations were made to remove nearly 15,000 cubic yards of contaminated soil from these areas. Removal of contaminated soil and the mill foundations was undertaken between May 1974 and August 1975. Ore-contaminated soil scraped from the ore-storage areas was dumped on the previously stabilized surface of the East Pile; though graded, contoured and reseeded, it was not covered with uncontaminated soil to prevent dispersal. Mill foundations were demolished and bulldozed into adjacent pits. The slope was then regraded to a maximum of 16 degrees and diversion ditches were constructed to minimize erosion by water. Radiologic surveys of the areas conducted after completion of these cleanup activities indicated that the exposure rates were reduced to no more than 0.04 mR/hr above the background rate of 0.02 mR/hr.

2.2.6 Recent DOE Remedial Action

In 1980, the U.S. Department of Energy (DOE) placed the Monticello millsite into the Surplus Facilities Management Program (SFMP) and the Monticello Remedial Action Project (MRAP) was established. In 1983, remedial activities at vicinity properties were separated from MRAP with the establishment of the Monticello Vicinity Properties (MVP) Project. The peripheral properties were retained with the Monticello Mill Tailings Site (MMTS) as Operable Unit (OU) II.

The DOE entered into a Federal Facilities Agreement (FFA) with the U.S. Environmental Protection Agency (EPA) and the State of Utah in December 1988 to complete remedial action at the millsite, peripheral properties, and vicinity properties. The *Monticello Vicinity Properties Site Record of Decision* (ROD) was signed in November 1989. The *Monticello Mill Tailings Site ROD* covering the millsite (OU I) and the peripheral properties (OU II) was signed in September 1990. Groundwater and surface water (OU III) will be addressed in a separate ROD. In spring of 1991, OU III was elevated by DOE to project status with the creation of the Monticello Surface- and Ground-Water Remedial Action Project (MSGRAP).

2.2.7 Overview of Previous OU III Documents

Numerous documents have been prepared in support of the OU III RI/FS over the past several years. Due to scope of work and technical direction changes, several of these documents have been superseded by more recent documents. In addition, the RI/FS relies on the results of numerous previous sampling programs conducted within OU III and the surrounding area. A summary of historical and future sampling programs and documents associated with OU III is presented in Table 2.2-1. Existing documents that either supersedes or effectively incorporates information presented in earlier documents and future documents that will directly support completion of the RI/FS through the Proposed Plan and ROD are shown in boldface type in

Table 2.2-1. For example, historical data presented in pre-1994 data reports have effectively been incorporated into the *Baseline Characterization Data Summary Report* (DOE 1994b) and this Work Plan.

Section 2.0

Environmental Setting

Tables

September 1995

Table 2.2-1. Summary of Historical and Future Sampling Programs and Documents Associated with OU III.

	Pre 1990	1990	1991	1992	1993	1994	1995	1996	1997	1998
CERCLA Documents		MMTS Record of Decision and Record of Decision Summary								**Proposed Plan** **Record of Decision**
Plans			CERCLA Management Plan	Final Surface- and Ground-Water RI/FS Work Plan, Field Sampling Plan, Quality Assurance Project Plan to support the Baseline Characterization	Draft Project Management Plan Characterization of Sediment in Upper and Lower Montezuma Creek Canyon - Draft Work Plan/Field Sampling Plan	Draft RI/FS Work Plan, Field Sampling Plan, and Quality Assurance Project Plan Draft MMTS OU III Focused Work Plan for Confirmatory Soil Sampling	**Draft Final Monticello Site Management Plan** **Draft Monticello Projects Health and Safety Plan** **Draft Final RI/FS Work Plan, Field Sampling Plan, and Quality Assurance Project Plan**			
Reports	Annual Site Environmental Reports Aquatic Biology Survey-BIO/WEST	Annual Site Environmental Report Final RI/FS-EA for the MMTS	Annual Site Environmental Report	Annual Site Environmental Report	Annual Site Environmental Report	**Baseline Characterization Data Summary Report**			**RI/FS Report**	
Sampling Programs	Historical Surface-Water and Ground-Water Investigations 1982 - 1987 Sediment Sampling Programs 1988 Aquatic Biology Survey Historical Air Monitoring Programs			Baseline Characterization : Surface-Water and Ground-Water Monitoring	Baseline Characterization : Surface-Water and Ground-Water Monitoring	Annual Monitoring Program : Semiannual Surface-Water and Ground-Water Monitoring Confirmatory Soil Sampling Program	Annual Monitoring Program : Semiannual Surface-Water and Ground-Water Monitoring Biotic and Abiotic Sampling in Support of the Baseline Risk Assessment	Annual Monitoring Program : Semiannual Surface-Water and Ground-Water Monitoring	Annual Monitoring Program : Semiannual Surface-Water and Ground-Water Monitoring	Annual Monitoring Program : Semiannual Surface-Water and Ground-Water Monitoring

BOLD ITALIC = Documents that either supersede or effectively incorporate informatiion from earlier documents and future documents that directly support completion of the RI/FS through the Proposed Plan and Record of Decision.

3.0 Previous Investigations

3.1 Introduction

Environmental investigations at or near the MMTS began as early as 1955. While data from the early studies are sparse or not validated under modern protocols, recent work yields a substantial body of data describing existing conditions. These data form a basis for the investigative strategy on which the OU III RI/FS Work Plan relies. This section of the Work Plan summarizes previous investigations and their significance to the RI/FS.

Most previous investigations characterized either hydrologic conditions (surface and ground water), sediment properties, ecological conditions, or air quality. These investigations are summarized in chronological order under the proper topic heading. Each summary describes the work conducted and the general results attained. For each topic, the major findings of the investigations are then synthesized in terms of their significance for the Work Plan. Because they often do not meet present-day technical and documentation standards, data obtained before 1984 are generally interpreted only qualitatively. Recent data usually conform to current standards and can be quantitatively evaluated.

Other investigations were not reported individually in documents limited to specific topic headings. A geologic map and report of the millsite and the adjoining repository site were prepared in October and November 1989 to provide basic information for evaluating those sites. The resulting *Monticello Remedial Action Project, Surface Geologic Characterization of the Near and Far South Sites* (Goodknight and Werle 1990) contains information relevant to hydrologic, sediment, and ecologic studies. Other investigations made prior to 1989 are reported in the *Final Remedial Investigation/Feasibility Study—Environmental Assessment for the Monticello, Utah, Uranium Tailings Site* (the *RI/FS-EA*), (DOE 1990b). Routine monitoring of surface water, ground water, and air at the MMTS is documented in annual environmental monitoring reports for calendar years 1979 through 1993. These reports include Bendix (1980), Korte and Thul (1981, 1982, 1983, 1984), Korte and Wagner (1985, 1986), Sewell and Spencer (1987), and DOE (1988a, 1989, 1990a, 1991a, 1992b, 1993b, 1994a).

OU III data collection activities were initiated in 1992. The OU III activities conducted before development of this plan include surface water and ground-water monitoring (baseline characterization [1992-1993] and annual monitoring [1994-1995]), hydrogeologic site reconnaissance (1994), gamma radiation exposure rate survey (1994), geomorphic site reconnaissance (1994), and confirmatory soil sampling (1994). These activities are further discussed in the following sections.

Analytical data generated during the baseline characterization, annual monitoring, and confirmatory soil sampling events were used to develop the preliminary risk calculations presented in Sections 4.5 and 4.6. These data were also compared with regulatory benchmarks, as an initial means of identifying the analytes that occur at concentrations exceeding the benchmarks in each medium. Comparisons of analyte concentrations in ground water, surface water, and sediment/soil to regulatory benchmarks for human health are

presented in Tables 3.1-1, 3.1-2, and 3.1-3, respectively. As shown, surface water and ground-water data were obtained at upgradient, onsite, and downgradient monitoring sites. Sediment/soil data were obtained downgradient of the millsite. The analytes with maximum or average concentrations exceeding numerical regulatory benchmarks for human health (surface water and ground water) or potential numerical benchmarks for human health (sediment/soil) are summarized for each medium below.

Ground Water:	Upgradient	Onsite	Downgradient
	Radon-222	Radon-222	Radon-222
		Gross Alpha	Gross Alpha
		Gross Beta	Gross Beta
		Arsenic	Arsenic
		Lead	Lead
		Nitrate	Nitrate
		Selenium	Selenium
		Uranium	Uranium
		Radium-226	Barium
			Beryllium
			Nickel
Surface Water:	Upgradient	Onsite	Downgradient
	Uranium	Uranium	Uranium
	Gross Alpha	Gross Alpha	Gross Alpha
		Gross Beta	Gross Beta
		Selenium	Selenium
		Arsenic	
		Radium-226	
Sediment/Soil:			Downgradient
			Arsenic
			Beryllium
			Manganese
			Ra-226

Please note that insufficient data currently exist to compare OU III sediment/soil data with background concentrations. Sediment/soil background data are being collected as part of the RI.

Comparisons of analyte concentrations in surface water to Federal and State acute and chronic ambient water quality criteria for aquatic organisms are presented in Section 4.5. The analytes with maximum or average concentrations exceeding one or more of these criteria are summarized below:

Surface Water:	Upgradient	Onsite	Downgradient
	Aluminum	Aluminum	Aluminum
	Iron	Iron	Iron
	Lead	Lead	Lead
	Selenium	Selenium	Selenium
		Arsenic	
		Copper	
		Mercury	

3.2 Surface Water Investigations

3.2.1 Introduction

Montezuma Creek is a perennial stream that heads in the Abajo Mountains, flows from west to east past the millsite, and turns south at its confluence with Vega Creek on its way to the San Juan River. It is the main source of surface water in the Monticello area. Other bodies of water on the millsite and nearby areas include several small ponds, seeps, and drains. Section 2.0, "Environmental Setting," describes the surface waters in more detail.

As early as 1950, radium levels in Montezuma Creek were known to be increasing as a result of uranium milling. In 1955, Public Health Service workers noted that streamflows consisted mostly of overflow and seepage from the tailings ponds and measured a radium-226 activity of 160 picocuries per liter in Montezuma Creek below the mill (Tsivoglou et al. 1956; Tsivoglou 1964; Whitman and Beverly 1958). It was also known by 1954 that effluent releases from the mill contributed salts and other soluble contaminants to the creek. Water samples collected from March 1956 to March 1959 indicated higher pH values and elevated concentrations of total dissolved solids (TDS), sodium, carbonates and bicarbonates, sulfates, and chlorides in the stream water below the mill. Several studies were made during the last years of mill operations to find ways of correcting these problems (Bendix 1980). Only sporadic monitoring of surface water occurred between closure of the mill and 1979, when the present monitoring program began. Investigations carried out since 1979 fall into two categories:

- Routine monitoring of water quality, concentrating on radionuclides and metals typical of contamination associated with uranium mill tailings. These data were reported in the 1990 *RI/FS-EA*, although monitoring has continued since that time.

- Hydrogeologic reconnaissance and expanded water-quality sampling and analysis to support development of the OU III RI/FS Work Plan.

This section briefly summarizes both categories. Plate 2-2 shows the locations of the surface water monitoring stations referenced below. For further interpretation of the data obtained from these investigations, see Section 2.0, "Environmental Setting."

Table 3.1-1. Comparison of Analyte Concentratio.. ..t Upper Flow System Ground Water and Regulatory Benchmarks

Compound	Regulatory Benchmarks: Federal SDWA MCL ug/l	Regulatory Benchmarks: State of Utah Ground Water Quality Standard ug/l	Upper Flow Sysem Monitoring Summary - Since November 1992*: Upgradient Maximum ug/l	Upgradient Arith. Mean ug/l	Millsite Maximum ug/l	Millsite Arith. Mean ug/l	Downgradient Maximum ug/l	Downgradient Arith. Mean ug/l
Aluminum			3920	990.79	9670	1332.36	108000	3039.2
Antimony	6		2	1.04	1.4	1.2	1.9	0.69
Arsenic	50	50	5	1.99	469	76.13	131	14.06
Barium	2000	2000	147	66.94	286	53.12	2250	97.09
Beryllium	4		1.1	0.55	non detect	non detect	6.2	0.73
Boron			107	59.94	439	159.92	544	131.5
Calcium			517000	263911.1	606000	287419.99	408000	262058.33
Cadmium	5	5	non detect	non detect	3.2	0.63	2	0.54
Cobalt			non detect	non detect	24.9	7.87	61.2	8.68
Chromium	100	100	10.6	2.96	14	3.61	79.7	4.35
Copper		1,300	8.1	2.08	465	30.42	197	8.89
Lead		15	11.3	2.43	52.8	4.64	89.1	3.9
Manganese			520	96.22	12900	4118.68	11400	785.29
Mercury	2	2	non detect	non detect	non detect	non detect	non detect	non detect
Molybdenum			3.8	5.58	2150	472.71	240	87.21
Nitrate	44000**	44000**	20900	3863.81	286000	38338.24	53700	14052.92
Nickel	100		non detect	non detect	63.1	14	130	9.45
Selenium	50	50	5.1	2.84	302	30.87	57.4	15.59
Silver		100	non detect	non detect	6.7	2.19	non detect	non detect
Sulfate			120000	545699.99	238000	295116.66	132000	789266.86
Thallium	2		non detect	non detect	1.1	0.59	1.8	0.62
Uranium	20		7.3	4.86	12600	2072.34	2870	816.67
Vanadium			8.8	3.43	169000	13403.17	2890	348.2
Zinc		5000	40.5	15.22	78.7	18.38	500	22.13
Pb-210			non detect	non detect	79	14.1	21	6.42
Po-210			non detect	non detect	20.27	2.48	6.9	0.4
Ra-226	20 pCi/l***	5 pCi/l***	0.56	0.18	16.14	2.06	1.1	0.13
Ra-228	20 pCi/l***	5 pCi/l***	non detect	non detect	non detect	non detect	non detect	non detect
Rn-222	300pCi/L		1265	700.44	59651	4302.12	10591	1577.68
Th-230			0.45	0.11	1.06	0.51	0.91	0.49
Th-232			0.55	0.09	0.88	0.33	0.16	0.38
U-234			77.5	7.31	4096.4	686.53	968.26	272.23
U-235			0.49	0.11	194.37	45.29	41.32	13.27
U-238			77.53	5.86	4288.8	700.13	985.64	276.53
Gross Alpha	15 pCi/l	15 pCi/l	non detect	non detect	9780	1524.4	2300	586.78
Gross Beta	50 pCi/l		non detect	non detect	3300	494.25	1040	220.43

* Shaded values indicate an exceedance of at least one regulatory benchmark

** Derived from water-quality standard for nitrogen

*** Limit is for Ra-226 and Ra-228 combined

Table 3.1-2. Comparison of Analyte Concentrations in Montezuma Creek/Seeps and Regulatory Benchmarks

Compound	Regulatory Benchmarks			Montezuma Creek Monitoring Summary - Since November 1992*					
	Federal SDWA MCL ug/l	State of Utah		Upgradient		On site ##		Downgradient	
		Domestic ug/l	Agriculture ug/l	Maximum ug/l	Arith. Mean ug/l	Maximum ug/l	Arith. Mean ug/l	Maximum ug/l	Arith. Mean ug/l
Aluminum				1450	433	1360	443	3550	1007
Antimony	6			2	0.8	2.2	0.8	1.9	0.7
Arsenic	50	50	100	11	4.4	1250	139.6	15.1	2.8
Barium	2000	1000		141	83.9	117	56.1	103	64.4
Beryllium	4			non detect	non detect	non detect	non detect	non detect	non detect
Boron				140	69.21	403	133.22	130	73.29
Calcium				431000	165292.4	358000	202310	324000	146986
Cadmium	5	10	10	non detect	non detect	non detect	non detect	non detect	non detect
Cobalt				6.6	6.6	non detect	non detect	non detect	non detect
Chromium	100	50	100	4.9	4.9	non detect	non detect	26.3	5.1
Copper			200	10.1	10.1	65.1	6.4	10.7	2.5
Lead		50	100	24.5	1.9	5.1	1.2	6.5	2.1
Manganese				1000	266	785	167.6	460	183.9
Mercury	2	2		non detect	non detect	0.2	0.2	non detect	non detect
Molybdenum				20.2	10	2450	175	90.9	13.9
Nitrate	44000**	44000**		24600	4337.3	18500	5520.47	6190	746.99
Nickel	100			13.3	5	11.4	5.2	11.6	6.4
Selenium	50	10	50	9.7	2.2	540	38	19.6	2.3
Silver		50		non detect	non detect	non detect	non detect	non detect	non detect
Sulfate				100000	223611.9	138000	600493.33	787000	385105.55
Thallium	2			non detect	non detect	non detect	non detect	non detect	non detect
Uranium	20	30 pCi/l	(92 ug/l) @	103	19.8	3230	652.1	506	93.6
Vanadium				29.8	9.3	52000	3856.3	280	20.8
Zinc				34	11.7	38.3	12.3	86.7	24.6
Pb-210				non detect	non detect	33.8	5.48	2.7	1.17
Po-210				0.19	0.12	0.65	0.18	non detect	non detect
Ra-226	20 pCi/l***	5 pCi/l***		2.4	0.6	9.1	2.4	1.3	0.3
Ra-228	20 pCi/l***	5 pCi/l***		non detect	non detect	non detect	non detect	non detect	non detect
Rn-222	300 pCi/L								
Th-230				0.2	0.07	0.81	0.54	0.58	0.12
Th-232				0.09	0.06	non detect	non detect		
U-234				39.3	8.3	1064.7	228.3	176.5	33.9
U-235				0.09	0.08	42.9	10.6	4.9	1.1
U-238				38.1	6.9	1063.5	228.4	174.2	33.5
Gross Alpha	15 pCi/l	15 pCi/l	15 pCi/l	60	20.2	1900	369.8	350	68.73
Gross Beta	50 pCi/l	50 pCi/l	50 pCi/l	26.5	16.6	1164	164.4	130	25.8

* Shaded values indicate an exceedance of at least one regulatory or risk-based benchmark

** Derived from water-quality standard for nitrogen

***Limit is for Ra-226 and Ra-228 combined

On site data includes some seeps that are not in the main Montezuma Creek channel

@ Specific for Montezuma Creek

Table 3.1-3. Comparison of Analyte Concentrations in Sediment/Soil Samples[a] Collected from 0 to 6-Inches Below Ground Surface and Potential Benchmarks

Constituent	Benchmark[b] mg/kg	Mean[c] mg/kg	95% UCL[c] mg/kg	Maximum[c] mg/kg
Aluminum	78,000	8,503.1	11,511.8	21,923.2
Antimony	31	nondetect	nondetect	nondetect
Arsenic	0.37 to 23	7.4	13.6	12.7
Barium	5,500	169.1	245.7	260.0
Beryllium	0.15	0.5	0.7	0.7
Cadmium	39	0.2	0.6	0.8
Chromium	390 - 78,000	7.0	9.6	9.8
Cobalt	4,700	5.9	8.5	9.6
Copper	2,900	58.0	166.6	193.0
Iron	-	11,331.3	14898.2	15,000.0
Lead	-	13.0	19.8	22.5
Manganese	390	383.1	472.6	490.0
Mercury	23	0.02	0.03	0.03
Molybdenum	390	1.6	2.8	2.8
Nickel	1,600	10.8	13.1	12.6
Selenium	390	0.6	1.6	1.6
Silver	390	0.1	0.3	0.4
Thallium	6.3 - 7	0.2	0.5	0.6
Tin	47,000	nondetect	nondetect	nondetect
Uranium	230	16.4	41.3	26.5
Vanadium	550	105.7	341.2	488.0
Zinc	23,000	50.5	68.5	66.4
K-40	-	15.46 piC/g	25.37 piC/g	20.2 piC/g
Ra-226	5/15 piC/g	17.91 piC/g	61.38 piC/g	74.2 piC/g
Th-232	-	1.77 piC/g	4.38 piC/g	4.0 piC/g

[a] Samples collected during the 1994 confirmatory soil sampling event.
[b] Benchmarks are soil screening levels; obtained from the EPA Region III Risk-Based Concentration Table, January - June 1995.
[c] Shaded values indicate an exceedance of the regulatory benchmark.

3.2.2 Investigations Reported in the 1990 RI/FS-EA

The goals of the post-1979 monitoring program were (1) to compare water quality in Montezuma Creek upstream from the millsite with that at the millsite and downstream, (2) to characterize the type and extent of contamination in surface waters, and (3) to assess compliance with surface water quality standards. This program evolved in several steps over time:

- **1979.** DOE established surface water sampling stations at three locations—W-3 at the upstream limit of the millsite, W-2 at a seep on the millsite itself, and W-4 about 100 m downstream from the millsite. The constituents monitored included radium-226, metals, nitrates, and major anions.

- **1981-1983.** DOE added a fourth station (the Sorenson site), about 1.3 miles downstream from the millsite, to the sampling network in 1981. In addition, on-site seeps, nearby ponds, and other locations were sampled to mroe precisely define surface water contamination downgradient of the millsite and to evaluate the validity of site W-3 as a background sampling station. However, not all of these sites were routinely monitored thereafter. The Montezuma Canyon site, located near the confluence of Montezuma and Verdure Creeks, about 6 miles downstream from the millsite, was one of the surface water monitoring stations established in this interval.

- **1984-1986.** A total of 10 sites were sampled at varying frequencies during this period.

- **1987-1991.** From 1987 to April 1991, monitoring was scaled back from the previous program with the intent of detecting only major changes in water chemistry. Following this change, the new goals of the monitoring program were (1) to verify compliance with State surface water quality standards, and (2) to detect changes in water quality occurring after the start of remedial action.

The early investigations identified several relationships between contaminant sources on and near the millsite and water quality in the receiving stream. These relationships included the following:

- While the major sources of contamination are on the millsite, some contaminants enter Montezuma Creek at points upstream of the millsite.

- Although significant contamination enters the creek as it crosses the millsite, ground-water inflows just below the millsite also transfer high levels of contamination from the tailings piles to the creek.

- Contaminant levels at points further downstream vary with stream stages, especially during the spring runoff, and with the relative contribution of ground-water base flow from non-millsite sources.

- In the deep canyon downstream from Vega Creek, uranium concentrations reflect both contaminants derived from the millsite and naturally occurring uranium from mineralized formations exposed in the canyon walls.

Only minor amounts of constituents attributable to uranium milling were found at upstream stations. Aluminum and arsenic were not detected at all; barium, iron, manganese, molybdenum, selenium, uranium, vanadium, and zinc were found in low concentrations. The 1981-83 studies concluded that the upstream monitoring sites did not truly reflect background water quality because of their proximity to the millsite. However, these sites remained in use for general monitoring purposes.

On the millsite proper, uranium concentrations in the stream began to rise at points upstream from the tailings piles. Arsenic, molybdenum, vanadium, and uranium all increased at Site W-2, where a seep from the Carbonate Pile entered the creek, and uranium, molybdenum, selenium, vanadium, and radium–226 continued to increase below the Vanadium Pile. However, the highest levels of molybdenum and uranium were found downstream from the millsite. These high concentrations indicated that major contributions from the upper ground-water flow system to the creek occurred below the drop structure at the east boundary of the millsite.

Further downstream from the millsite, uranium concentrations at the Sorenson site depended heavily on discharge levels in Montezuma Creek. Concentrations decreased during periods of high flow (from March to June) and increased during base-flow periods (from July to February). In the canyon south of the Vega Creek confluence, elevated uranium levels typically occurred at the Montezuma Canyon site. Additional sampling in the canyon showed that a significant part of this uranium leached directly from the mineralized Salt Wash Member of the Morrison Formation, which cropped out in the canyon walls above the sampling station. Variations in concentrations of all solutes apparently reflected dilution by spring runoff and by inflows of better-quality ground water from the Entrada Sandstone (DOE 1990).

3.2.3 Pre-RI/FS Activities

After issuance of the 1990 *RI/FS—EA*, the emphasis shifted from routine monitoring to studies that focused on potential remediation of OU III. Expanded chemical analyses showed that, in addition to the radionuclides, metals, and general chemistry constituents reported earlier, the gross alpha activity and nitrate concentrations in millsite surface water exceeded State and Federal standards (DOE 1992b). Other work supporting the OU III RI/FS included the following.

- **1992-1993.** An OU III baseline characterization that began in November 1992 included four surface water sampling events at 16 sites. In addition to the four existing stations on the creek (W-2, W-3, W-4, and Sorenson), DOE sampled nine new sites along Montezuma Creek. Three of these were upstream from the millsite, two were on the millsite, and four were located downstream. The remaining four sites were ponds or seeps at the millsite. DOE also began monthly streamflow measurements at the 12 sites on Montezuma Creek. A baseline characterization report (DOE 1994c) documents the results, which are summarized in Section 4.4 of this work plan.

- **1994.** DOE made a hydrogeologic reconnaissance to aid in developing a hydrologic conceptual model for the MMTS. This reconnaissance included mapping the seeps and springs on the north and south flanks of upper Montezuma Creek. The goal of this work

was to assess the occurrence and significance of interflow between upper Montezuma Creek and the upper ground-water flow system on the MMTS. The locations of seeps and springs indicated the approximate levels of shallow ground water and supplied a basis for interpreting the extent and magnitude of contaminant migration to the stream.

The 1992-93 results showed that gross alpha activity and molybdenum, selenium, and uranium concentrations in the creek tended to be higher immediately downstream of the millsite than upstream of, or at, the millsite. Ground-water seeps were visible along the creek below the millsite, and stream flows increased steadily along a 1.2-mile reach downstream from the east millsite boundary. Higher concentrations of tailings-related contaminants were found in samples from ponds and seeps than in those from Montezuma Creek because the ponds and seeps were in direct communication with the millsite ground water and undiluted by stream runoff.

Concentrations of TDS exceeded State standards in samples from the upstream sites. At the millsite locations, the levels of selenium, TDS, and gross alpha activity exceeded the standards. Levels of arsenic, iron, nitrate, selenium, TDS, gross alpha and beta activity, radium–226, and radium–228 exceeded State standards in one or more of the pond and seep samples. Downstream from the millsite, samples from the creek exceeded standards for iron, pH, selenium, TDS, gross alpha activity, and gross beta activity. No significant amounts of any organic compounds on the Target Compound List (TCL) were found in surface water samples (DOE 1994a).

The hydrogeologic reconnaissance mapped five perennial seeps on the north slope of the MMTS, north of the millsite. One spring (Slade Spring) was found on upper Montezuma Creek, south of the BLM compound. No significant perennial seepage was found on the south slope. Three of the seeps on the north slope (Pehrson 1, Pehrson 2, and Upper North Drainage) were surveyed and sampled for water quality. The remaining two (Clayhill and Goodknight), as well as Slade Spring, will be surveyed in 1995.

3.3 Ground Water Investigations

3.3.1 Sequence of Investigations

Ground-water investigations at the MMTS focus mainly on three hydrogeologic units present on and near the millsite:

- an upper ground-water flow system, including the alluvial aquifer of Montezuma Creek;
- the Mancos Shale/Dakota Sandstone aquitard; and
- the Burro Canyon aquifer, including ground water in the Burro Canyon Formation and certain basal units of the Dakota Sandstone.

Section 2.4, "Hydrologic Setting," and Section 4.4, "Baseline Characterization," of this Work Plan describe these hydrogeologic units, their interrelationships, and the quality of the water in them. Three categories of ground-water investigations exist:

- Drilling of exploratory monitoring wells, followed by routine measurement of water levels and water-quality sampling, with a concentration on radionuclides, metals, and major ions. These data were reported in the 1990 *RI/FS—EA*, although monitoring has continued since then.

- Water levels and sampling results derived from remedial design investigations conducted for OU I. These sampling data likewise emphasize on radionuclides, metals, and major ions. Some of this work began before issuance of the 1990 *RI/FS—EA*; however, the data were reported in various design reports (cited below) rather than in that document.

- Hydrogeologic characterization and expanded water-quality sampling and analysis planned specifically to support development of the OU III RI/FS Work Plan.

This section briefly summarizes the three categories. Plate 2-2 shows the locations of the monitoring wells referenced below.

3.3.2 Groundwater Monitoring Reported in the 1990 RI/FS-EA

DOE first monitored ground-water levels and quality in 1980. However, the sophistication and extent of the monitoring program improved greatly after about 1984. Major steps in the evolution of the program included the following.

- **1980-1982.** DOE installed five shallow wells into the upper ground-water flow system at the millsite area in 1980. However, these wells were screened across more than one water-bearing unit and the well casings were loose so that foreign matter could fall into the annular space around the casings. For these reasons, samples from them do not necessarily represent conditions in the upper flow system accurately. DOE also sampled four privately owned wells, one at a downstream location and three upgradient from the millsite. The samples were analyzed for radiological constituents, metals, and inorganic major ions. DOE sampled these wells semiannually until 1982 (DOE 1990a).

- **1982.** DOE installed 32 monitoring wells in the upper ground-water flow system. Ten of these wells were screened across the upper flow system and parts of either the Mancos Shale or the Dakota Sandstone. In spring 1983, DOE performed slug tests in 14 of the monitoring wells to obtain estimates of hydraulic conductivity. Results of the 1982 field studies are documented in a *Site Analysis Report* (Bendix 1984) and in the *RI/FS—EA*.

- **1983-1984.** Eight boreholes were drilled and cored into the Dakota Sandstone and the Burro Canyon Formation. Five of the boreholes were completed as monitoring wells, three (84-75, 84-76, and 84-77) in the Burro Canyon aquifer and two others (83-70 and 84-74) in both the Dakota Sandstone and the Burro Canyon aquifer. DOE sampled all five wells in 1986 and continued sampling one of them (84-74) through July 1993, giving the results in the annual environmental monitoring reports. These five wells allowed water quality in the Dakota Sandstone and Burro Canyon aquifer to be compared at upgradient (but east of U.S. Highway 191), millsite, and downgradient locations. Three pumping

tests were made at well 83-70 to estimate the hydraulic properties of the Burro Canyon aquifer. The test results were reported in DOE (1984) and in the *RI/FS—EA*.

- **1986-1988.** DOE completed three wells in the upper ground-water flow system at the millsite in 1986 and 10 more wells in 1988. Pumping tests were made in two of the wells to aid in evaluating on-site stabilization alternatives for remediating the tailings. The 1988 results were documented in a summary report (DOE 1988c).

- **1987.** Semiannual sampling resumed at 13 monitoring wells located upgradient, on site, and downgradient of the millsite. The analytes included gross alpha activity, radium–226, radium–228, uranium, vanadium, arsenic, selenium, molybdenum, and nitrate. Total alkalinity, pH, and specific conductance also were measured to detect changes in general water-quality characteristics. Water levels were measured quarterly (DOE 1988a).

The results of these investigations are discussed in later sections of this Work Plan. However, some of the primary findings include the following:

- Water-quality data obtained before 1987 are of limited value for quantitative analysis because they, or the wells from which they were obtained, did not conform to technical or quality-assurance protocols that are now (1995) standard practice. Data collected after sampling resumed in 1987 are significantly more reliable.

- Qualitatively, the older data indicated widespread contamination of the upper ground-water flow system by radionuclides and metals in the millsite area. Nitrates, sulfates, and chlorides were also present at elevated levels.

- The data confirmed findings of the surface water studies that contaminants tended to move along the valley floor from the tailings piles to downstream reaches of Montezuma Creek.

- No evidence of millsite-related contamination was found in the limited investigation of waters in the Dakota Sandstone and the Burro Canyon Formation.

3.3.3 Operable Unit I Remedial Investigations

Upon completing the *RI/FS—EA*, DOE made several investigations to support implementation of the selected remedies for OU I. These design-stage investigations focused on either the millsite or the area south of the millsite (the South Site) proposed for permanent storage of the uranium mill tailings and related contaminated materials. However, many data regarding hydraulic properties and water quality in bedrock hydrogeologic units can be extrapolated to OU III conditions.

- **1989-1991 Characterizations of the South Site.** DOE obtained a hydrogeologic and geotechnical study of the South Site in 1989 and 1990 to evaluate its suitability for the OU I repository. This study included the drilling, logging, and geotechnical sampling of 82 drillholes, in which monitoring wells were installed and developed. Most of these wells penetrated only a short distance into weathered Mancos Shale. However, 14 drillholes were carried deeper into the Mancos Shale, the Dakota Sandstone, or the Burro Canyon

Formation by and rotary core drilling. Both field packer tests and laboratory permeability tests were performed. A *Final Report* (Golder Associates Inc. 1990) presented the results of this characterization. Additional studies were made in 1991 to further define hydrogeologic conditions, aid in locating the repository within the overall South Site, and evaluate the properties of potential construction materials (Golder Associates Inc. 1991). These included auguring 15 more drillholes and coring four angled drillholes to evaluate fracturing in the bedrock formations. Thirteen of the auger holes were completed as piezometers or monitoring wells. Packer tests were made in the angled drillholes, and a short-duration pumping test was made in a well penetrating the weathered Mancos Shale.

- **1991 Characterization of the Millsite.** A field investigation began in 1991 to gather design-level geotechnical, hydrogeological, and radiological data at the millsite and the BLM area. This work included installing 38 monitoring wells and 20 standpipes in the Montezuma Creek alluvium and one monitoring well in the Mancos Shale, developing the monitoring wells, performing well-recovery tests, and collecting and testing geotechnical, chemical, and radiological samples. The results of this investigation were reported in a *Revised Final Report* (Dames & Moore 1992).

- **1993 Evaluation of Repository Alternatives.** In April 1993, DOE began investigating proposed alternatives to constructing a repository on the central part of the South Site. The goal was to obtain enough hydrogeologic, geotechnical, regulatory, civic, and cost data for each alternative to determine if the selected remedy for OU I should be changed. Two of the alternatives were (1) to stabilize tailings and other contaminated materials in a repository on the millsite, and (2) to build a repository on the north part of the South Site, adjacent to the millsite. The field work to assess these two alternatives included installing __ new monitoring wells, packer testing, geophysical logging, water-level measurements, and ground-water sampling. In addition, work began on a MODFLOW numerical model of two layers—the upper flow system and the Burro Canyon aquifer—at the millsite area using a 300- by 300-ft rectangular grid. This modeling was suspended at the calibration stage when DOE elected to drop the two alternatives from further consideration. A *Data Summary Report* (DOE 1994b) documented the work performed for this investigation.

3.3.4 1992-1994 Pre-RI/FS Activities

A review subsequent to the *RI/FS—EA* identified the modifications needed for a ground-water monitoring network to establish baseline conditions. Some previously sampled monitoring wells that were removed from the network because they were not representative of ground-water conditions (e.g., background location, specific hydrogeologic units) (DOE 1992e). Following this review, a baseline characterization study began in September 1992 to assess the nature and extent of pre-remediation contamination in surface and ground waters at the MMTS. This work included mapping the seeps and springs on either side of upper Montezuma Creek to evaluate the occurrence and significance of shallow ground-water flow from the flanks of upper Montezuma Creek to the central portion of the upper flow system on the MMTS. Mapping of seeps and springs would indicate approximate shallow ground-water levels in these areas where few to no wells exist and allow a more valid extension of the upper flow system ground-water elevation

contour map outward from the upper Montezuma Creek area. Because the north and south flanks of the MMTS are considered upgradient sources of ground water to the upper flow system on the MMTS, background water quality in these areas was also of interest. Background water quality information of upgradient sources has potential application to OU III remediation goals including input to the ground-water model. The results of the baseline characterization are reported in the *Monticello Mill Tailings Site, Operable Unit III, Baseline Characterization Data Summary* (DOE 1994c) and are summarized in Section 4.4 of this report.

Upon completion of the baseline characterization, the monitoring network and the sampling strategy were altered. Several analytes (antimony, beryllium, cyanide, mercury, and strontium) were deleted from the sampling network because of their consistently low concentrations or lack of association with uranium mill tailings. Some wells were replaced in the sampling network because of low water volume, and some wells were abandoned (DOE 1994a). Surface water and ground-water monitoring will continue at least through completion of the OU III RI/FS.

A private well survey was conducted in 1994 to obtain additional water-level information north of the MMTS. Ground-water elevations north of the MMTS would allow the construction of local-scale (2-mile radius of MMTS) ground-water elevation contour maps that would be used to calculate local ground-water gradients and verify conceptual flow directions. Of 30 private owners contacted, only 5 owners volunteered to have water-level measurements taken at their wells. The results of these measurements are of limited use because of the high uncertainty of relating water levels to well-screen locations (as a result of poor drill log information), and the overall sparsity of measurements. However, other information gained from the private well survey was that both private individuals and public (City of Monticello) owners of deep wells (lower Dakota Sandstone, Burro Canyon) do not operate them often. Some wells have remained dormant for ten years or more, depending on spells of drought. A representative of the City of Monticello stated that as demand for municipal water increases with population growth, other surface water rights would be pursued before supplementing demand with a major pumping operation (Schafer 1994).

Forty-six slug tests were performed on upper flow system wells during the summer of 1994. The goal of the slug test program was to support the hydrologic site conceptual model by gaining a more complete understanding of the spatial variability of hydraulic conductivity estimates, and therefore, the scale of heterogeneity of the upper flow system deposits, over a broad area of the MMTS. In addition, the resulting extensive distribution of hydraulic conductivity data would supplement previous pumping test conductivities as input to the OU III ground-water model. The objective was to conduct slug tests on wells that were screened in native alluvium upgradient, on, and downgradient of the millsite. Of the 46 tests conducted in 1994, 4 were upgradient, including 1 duplicate; 26 were on the millsite, including one duplicate; and 16 were downgradient, including 3 duplicates. The arithmetic and geometric mean for all 46 tests was 1.2×10^{-2} and 1.7×10^{-3} cm/sec, respectively. The range was 5.2×10^{-5} to 1.5×10^{-1} cm/sec. The contribution of the slug testing work to the overall site conceptual model is discussed in Section 4.7.3.

3.4 Sediment Investigations

3.4.1 Sequence of Sediment Investigations

Three studies were performed between 1982 and 1987 to investigate sediments contaminated by radium–226 along the upper and lower portions of Montezuma Creek. Except in the first (1982) investigation, analyses were not made for other radioactive or nonradioactive constituents of uranium mill tailings. In 1994, DOE began several sediment-related studies specifically planned to support the OU III RI/FS Work Plan. The 1994 work included limited confirmatory sampling of soil and sediment deposits for both radionuclides and metals. Appendix B summarizes the analytical results, field measurements, and sample locations for the various investigations.

3.4.2 1982 Sediment Sampling

In 1982, DOE sampled sediments at 15 sites along the Montezuma Creek channel from about 1 mile upstream of the millsite to about 4.25 miles downstream from the confluence with Vega Creek (Appendix B, Figure B-1). Of the 15 sites, 1 site was located upstream of the millsite (west of U.S. Highway 191), one site was in the middle of the millsite, 8 sites were between the millsite and Vega Creek, and 5 sites were downstream from the Vega Creek confluence. At 14 sites, 3 discrete sediment samples were collected from various positions in or adjacent to the creek channel. At the remaining site, 1 sample was obtained by scraping surface coatings from rocks in the channel. All samples were analyzed for radium–226, uranium, vanadium, molybdenum, arsenic, and selenium. The results of the 1982 study were reported in an internal memorandum, *Stream Sediment Survey of South Creek and Montezuma Canyon* (Bendix 1982).

At the upstream site, radium-226 activities ranged from 0.4 to 1.0 picocurie per gram (pCi/g); those for uranium were less than or equal to 1.0 pCi/g. Vanadium ranged from 65 to 85 parts per million (ppm), molybdenum ranged from 4 to 7 ppm, and arsenic ranged from 4 to 6 ppm. Selenium concentrations were below the detection limit of 5 ppm.

Radium–226 activities ranged from 1 to 54 pCi/g downstream from the millsite and equaled or exceeded 5 pCi/g at all locations between the millsite and a site one-eighth mile below the Vega Creek confluence. Elevated concentrations of uranium and vanadium also were detected in these samples. Selenium was not detected at a detection limit of 5 ppm, and molybdenum and arsenic did not vary significantly from background in any of the samples. All samples collected further downstream than one-eighth mile below the Vega Creek confluence contained radium–226 and uranium at approximately background levels (Bendix 1982).

3.4.3 1984 Radiological Characterization

DOE conducted a radiological characterization of peripheral properties near the millsite in July and August of 1984. The main study area was a section of Montezuma Creek between the east boundary of the millsite and a point about 6,000 feet east of the millsite (Appendix B, Plates B-1 through B-8). A total of 52 sites were sampled in this area. In addition, one site was located at

the Vega Creek confluence and two sites were located about 1,250 ft west of Vega Creek, one along Montezuma Creek and one along an unnamed tributary. Results of the characterization were reported in Bendix (1985) and are tabulated in Appendix B, Tables B–2 and B–3.

Most of the sample sites were on the banks of the creek in depositional areas; none were located in the ponds along the creek. At each site, sediment samples were collected in 6-inch intervals from shovel holes. Measurements of radium–226 activity were made at each interval using a delta scintillometer. Sampling continued to a maximum depth of 24 inches or until field measurements indicated a radium–226 concentration lower than 6.0 pCi/g. Gamma exposure rates also were measured at ground level and waist level. Laboratory analyses for radium–226, thorium–232, and potassium–40 were performed on the samples. However, elemental analyses for uranium or other metals were not made. At several sites, both laboratory and field data showed radium–226 activities higher than 15 pCi/g at the 24-inch maximum depth. The highest Ra-226 concentrations occurred along the tops of the banks rather than at the water level. At isolated locations, ground-level gamma exposure rates exceeded the average background by a factor of ten (Bendix 1985).

A background study was made during 1984 to estimate average gamma exposure rates and radium–226 activities attributable to natural sources. Four background locations assumed to be representative of local geological conditions were selected within a few miles of the millsite. At each site, 6-inch-deep soil samples were collected from two discrete locations for submission to the laboratory and gamma exposure rates were measured with a pressurized ionization chamber. The resulting estimates of average background were 1.0 pCi/g for radium-226, 1.7 percent for potassium-40, 7 ppm for thorium-232, and 15 microroentgens per hour (μR/h) for the gamma exposure rate (Bendix 1985).

3.4.4 1985 Geotechnical and Radiological Characterization

A geotechnical and radiological characterization of the millsite and nearby peripheral properties was made in August 1985 to support preliminary design of remediation concepts. This work included the auguring of 22 drillholes and the coring of eight drillholes, downhole radiologic logging, in-place permeability testing, and (4) collection of soil samples from contaminated areas and potential sources of borrow material for geotechnical and radiological analyses. Results of this characterization are reported in a *Data Collection for Engineering* report (Bendix 1986).

3.4.5 1987 Sediment Sampling

DOE sampled sediment along upper and lower Montezuma Creek again in July 1987 to support preliminary engineering design for the peripheral properties. Ten sample sites were established at intervals of approximately 1,000 feet along the creek, beginning 4,000 ft. east of the millsite and ending at the Vega Creek confluence (Appendix B, Tables B-2 and B-3). The sites were selected visually to be representative of a variety of stream-channel physical characteristics. At each site, discrete samples were collected in the creek bed and on each bank to give a cross section of the sediment deposits. Where practical, sample points were also located outside of the apparent depositional areas on both sides of the creek. However, samples were not collected from any of the ponds along Montezuma Creek. The results were reported in a *Supplemental Data Release* (DOE 1991b) and are tabulated in Appendix B, Tables B–2 and B–3.

Samples were collected from shovel holes at six-inch intervals to a minimum depth of 12 inches. If delta-scintillometer measurements indicated elevated radium–226 levels, additional samples were collected at greater depths. Sampling continued to a maximum depth of 24 inches unless an obstruction was encountered. All samples were analyzed for radium–226, thorium–232, and potassium–40, but elemental analyses were not made for uranium or other metals. Gamma exposure-rate measurements were not made (DOE 1991b).

The 1987 data indicated that radium–226 levels in sediments along the creek banks were usually higher, and extended to greater depths, than those in the creek bed. The highest radium–226 activity measured in samples collected on the banks was 208 pCi/g at a depth of 18 to 24 inches. At several locations along the banks, field and laboratory data yielded radium–226 activities exceeding 15 pCi/g to depths greater than 24 inches. In samples collected from the creek bed, the highest radium–226 activity was 42 pCi/g measured at a depth of 0 to 6 inches. Samples from depths greater than 6 inches in the creek bed displayed activities lower than 8 pCi/g.

3.4.6 1994 Pre-RI/FS Activities

3.4.6.1 1994 Gamma Radiation Exposure Rate Survey

DOE surveyed gamma exposure rates at ground level in April 1994 to define the approximate extent of radiological contamination in OU III and to judge if the contamination displayed any pattern that suggested a sampling stratification. This survey covered Montezuma Creek and its floodplain from the west boundary of Property MP-00951 to about 0.5 miles below the Vega Creek confluence. Within Properties MP-00951 and MP-00988, the survey extended only to the already defined boundary between OU III and the OU II peripheral properties. Fieldwork consisted of scanning the survey area with a scintillometer to locate contours at predetermined values of gamma exposure rate. The scintillometer, an analog rate meter with a detector assembly mounted on an extended-arm aluminum crutch, measured gross gamma activity in counts per second (cps). These readings were converted to gamma activity in microroentgen/hour (μR/hr) using instrument-specific calibration factors.

The average background gamma exposure rate of 15 μR/hr (Bendix 1985) approximately corresponded to a scintillometer count rate of 125 cps. On this basis, the contour values to be located were set at 130 percent of the background count rate (160 cps, or about 18 μR/hr), 200 percent (250 cps, or about 24 μR/hr), and 1,000 percent (1,250 cps, or about 97 μR/hr). The scintillometer operators marked each contour on the ground with paint. Each contour was then plotted on a field map by referencing survey points and topographic and structural features. The field maps also recorded the minimum and maximum gamma activities for each area enclosed by the contours and the locations of patches of elevated gamma exposure rate too small to map accurately. Plates B-1 through B-8 present the resulting data.

3.4.6.2 1984 Photographic and Site Reconnaissance

In March and April 1994, DOE studied aerial photographs, dating from 1937 through 1989, of Montezuma Creek between the millsite and the reach below the Vega Creek confluence. The

purpose of this study was to map geomorphologic features that might define useful sampling strata, to map the migration of Montezuma Creek across its floodplain in the period since the mill began operation, and to assess the permanence of ponds and impoundments along the creek during that period. It was originally hoped that the study would resolve specific depositional settings such as point bars and overbank deposits as the creek meandered and shifted position over time. These presumably would be logical locations for contaminant accumulations.

The aerial photography study yielded mixed results. First, it found that the Montezuma Creek channel had not shifted discernibly since 1937. The creek channel is slightly incised so that meanders are inactive in this time frame. It is apparently at steady-state equilibrium in graded time (Schumm 1977). A shift from equilibrium requires a threshold-crossing flood; that is, one large enough to alter the channel form. Such a flood evidently has not occurred since 1937. Point bars formed in this period are small-scale, transient deposits along the active channel, and post-1937 deposits elsewhere on the floodplain are mostly overbank deposits, regardless of whether they occur on the insides of meanders or elsewhere. Second, the study could not resolve specific depositional settings without field mapping because of the scale and quality of the photography. The interpreters could resolve the limits of the channel itself and of the floodplain, but could not distinguish individual bars or subtle differences in the low-level terraces. Third, the study results show that the beaver ponds in the reach above the narrow canyon segment of Montezuma Creek were persistent features in all the photographs since 1937. However, the interpreters could not resolve the smaller ponds individually in all photographs, nor could they determine if the ponds had been breached and reconstructed.

Because the photographic study was inconclusive, a field reconnaissance was made on May 5, 1994 by an ecologist, an engineer, geologists, and a specialist in river mechanics and fluvial geomorphology. The areas visited included the beaver ponds east of the millsite, the reach from the abandoned cabin to about 0.5 miles below Vega Creek, and the confluence of Montezuma and Verdure Creeks. Major observations include

- The channel near Verdure Creek is deeply incised, probably reflecting the general arroyo formation that began about 1880 throughout the southwest. However, the channel in the canyon near the Vega Creek confluence is relatively unincised due to bedrock control.

- Closure of the Monticello Reservoir dam on South Creek may or may not have reduced sediment movement in Montezuma Creek after 1985. Most years since 1985 were drier than normal, so reduced stream flows cannot not be attributed solely to the dam. In the future, the dam will reduce peak discharges from snowmelt and general storms but may not affect thunderstorm floods as much. Thunderstorms yield high rainfall intensities over small areas, so that a thunderstorm centered elsewhere in the watershed could produce a large flood on Montezuma Creek without any flow contributed by South Creek.

- The main stem of Montezuma Creek shows little evidence of large floods in recent years. However, recent bank erosion and relatively unvegetated flash-flood deposits indicate that Verdure Creek apparently has undergone such a flood within the past few decades.

- The bed material is mostly sand sized. Finer-grained sediment apparently moves as wash load rather than bed load during periods of high discharge. Little or no sediment moves as either bed load or wash load during low-flow periods. Discharges large enough to move significant amounts of streambed sediment may occur a few times a year, probably in response to summer thunderstorms. The creek is now degrading its channel, with more sediment leaving the reach than entering it.

- The active stream channel has an estimated conveyance capacity of about 20 to 30 ft^3/s. The floodplain and low-lying terraces can convey flows of about 500 ft^3/s. The vegetation age classes present on various terrace levels suggest that floods of about 100 to 500 ft^3/s may occur every 2 to 5 years.

- Except in eddys behind obstructions and a few sandbars, the channel sediments appear free of radiological contaminants. The character of the sediment and the stream suggest that contaminants in the streambed largely have been flushed from the system or reworked and redeposited as other types of sedimentary deposits.

- In the canyon near Vega Creek, surfaces about 1 to 3 ft. above the stream often displayed higher gamma exposure rates than did lower lying areas. The relatively lower gamma exposure rates near stream level may reflect nondeposition of contaminated sediment near the stream, later erosion of contaminated sediment deposits, deposition of uncontaminated sediment over contaminated sediment, or combinations of these processes.

- The exposed margins of beaver ponds yielded gamma exposure rates that were among the highest recorded (as high as 157 μR/hr). Radioactive tailings slimes too fine-grained to be preserved elsewhere in the canyon may form deposits in the ponds and bogs.

- Contaminant levels along steep, narrow reaches of the canyon may be lower than elsewhere because high turbulence in these reaches during floods may tend to keep contaminated sediments in suspension.

- Riparian vegetation has partially stabilized contaminated sediments at higher levels on the floodplains and terraces. Large-scale re-entrainment of these sediments would require a flood large enough to destroy the vegetation and scour out the surficial soil.

3.4.6.3 1994 Confirmatory Soil Sampling

In mid-1994, the DOE, EPA, and the State agreed that the existing radium–226 data were insufficient to support development of the RI/FS without confirmation. Accordingly, DOE conducted a limited-scale investigation of soil contamination starting about 1,950 ft. east of the millsite and ending just past the Vega Creek confluence. A few sediment samples from ponds along Montezuma Creek were also obtained. The goal of this investigation was to confirm or qualify the 1984-87 data and to provide supporting data for the RI/FS and for DOE's own use.

For radiological contamination, replicate measurements were made at 14 of the 1984-87 locations using the same field methods (Plates B-1 to B-8). Sampling continued at each location until the radium-226 activity fell below 5.0 pCi/g, or to a maximum depth of 24 inches. This sampling strategy yielded 40 samples, not including quality-control samples. In addition to laboratory and field measurements of radium-226, gamma exposure rates at the ground surface were measured and laboratory analyses of radionuclides and metals were made. Grab samples were collected from the uppermost 6 inches of sediment near the inlets of the two ponds nearest the millsite. These samples were also submitted for laboratory analysis of radionuclides and metals. Tables B–4 and B–5 (Appendix B) summarize the results for metals and radionuclides, respectively.

3.5 Ecological Investigations

3.5.1 Summary of Ecological Investigations

Previous ecological investigations include surveys of aquatic biology, vegetation, and wetlands and a literature search to compile a potential list of threatened, endangered, and sensitive species of concern in the Monticello area. Ecological and human health risk assessments also were made for OU I and OU II. These were documented in the *RI/FS—EA* (DOE 1990b).

3.5.2 Aquatic Biology Studies

An aquatic biology survey of Montezuma Creek was made at four sampling stations along the creek in September 1988. The sampling stations included:

- Station A, just upstream of the millsite;
- Station B, just downstream of the millsite;
- Station C, about three-quarters of a mile east of the millsite; and
- Station D, approximately 0.5 mile upstream of the confluence of Montezuma Creek and Vega Creek.

Samples were collected along transects at Stations A, B, and C, while only qualitative data were collected at Station D. Results of the 1988 survey are documented in *An Aquatic Biology Survey* (BIO/WEST, Inc. 1988).

The flow rate, gradient, depth, velocity, stream width, substrate, pool-riffle habitat ratio, and presence of aquatic vegetation were described in the field. Both historic (before construction of Loyd's Lake) and recent flow regimes of Montezuma Creek were considered. Water samples were analyzed for temperature, pH, total alkalinity, iron, sulfate, and specific conductance. The periphyton, phytoplankton, benthic macroinvertebrates, and fish were surveyed to determine of species composition, diversity, and abundance. Periphyton were collected by scraping cobbles, and phytoplankton were collected with plankton buckets. Benthic invertebrates were collected using a modified Hess sampler at sites with cobble and rubble substrates. A ponar dredge was used for sand or silt substrates. A generator-powered backpack electroshocker was used to sample for fish, but none were found (BIO/WEST, Inc. 1988).

The survey indicated that periphyton was relatively diverse and composed of species that were primarily alkaliphilious, tolerant of moderate to high conductivities, or relatively indifferent to water quality. A true plankton population was not found. Instead, the plankton component was composed of periphyton species entrained into the water column. Periphyton and plankton did not appear to be adversely affected by water quality within the study area. The survey also indicated that aquatic invertebrates were relatively abundant. Species composition mainly consisted of taxa that were tolerant to a wide range of water quality conditions. Invertebrate diversity and densities were highest in the lower portions of the study area.

3.5.3 Vegetation Studies

Western Resource Development Corporation conducted a vegetation survey in 1988. A plant ecologist mapped croplands and native vegetation types in Montezuma Canyon and made quantitative field studies to estimate cover, production, and woody plant density for the three native vegetation types (riparian, mixed-shrub shrubland, and rubber-rabbitbrush shrubland). Results of the vegetation study are reported in *Monticello Remedial Action Project Peripheral Properties Vegetation Survey 1988, San Juan County* (Western Resource Development Corporation 1988) and in the *RI/FS—EA*.

3.5.4 Wetlands Studies

In August 1989, representatives of the U.S. Army Corps of Engineers and the DOE surveyed Montezuma Creek canyon representatives to estimate the wetlands acreage in the vicinity of the MMTS. However, this assessment did not constitute an official wetlands assessment. Eight wetland zones were tentatively identified between Highway 191 and the Vega Creek confluence for an estimated a combined area of 18.35 acres. Results of the wetland assessment are reported in *Monticello Remedial Action Project, Floodplain/Wetlands Assessment* (DOE 1990c). Because wetlands were only roughly delineated during this assessment, a more accurate wetlands assessment will be required.

3.5.5 Threatened and Endangered Species.

The Montezuma Creek canyon was surveyed for endangered plant species as part of the 1988 vegetation survey (Western Resource Development Corporation 1988). This study identified the Uinta Basin hookless cactus (threatened) and the spineless hedgehog cactus (endangered) as plant species of concern. Since then, however, both species have been delisted. A literature search made in 1993 indicated no threatened or endangered plant species specifically known to exist in the Montezuma Creek area. However,

Table 3.5-1 lists threatened, endangered, proposed endangered, probably extinct, candidate, and sensitive plants and animals expected to inhabit, or that once inhabited, San Juan County (U.S. Fish and Wildlife Service, personal communication, 199?).

Table 3.5-1 Threatened and Endangered Species Listed for San Juan County, Utah

Federally Listed Species, by Category			
Threatened (T)	**Endangered (E)**	**Proposed Endangered (PE)**	**Probably Extinct (3A)**
Navaho Sedge	Bald Eagle *(proposed for downlisting to threatened status in Utah in 1994)*	Mexican Spotted Owl	Relict (*and* Vegas Valley) Leopard Frog
	Peregrine Falcon		
	Black-footed Ferret		
	Bonytail Chub		
	Humpback Chub		
	Colorado Squawfish		
	Razorback Sucker		

Federally Listed Category 2 (C2) Candidate Species		
Allen's (Mexican) Big-eared Bat	Western Least Bittern	Navaho Mountain Beardtongue
Pales Townsends Big-eared Bat	Northern Goshawk	Beck Biscuitroot
Big Free-tailed Bat	Ferruginous Hawk	Alcove Bog-orchid
Spotted Bat	White-faced Ibis	Hole-in-the-rock Prairie Clover
North American Lynx	Western Burrowing Owl	Depauperate Daisy
Fringed Myotis (Bat)	Black Tern	Kachina Daisy
Long-eared Myotis (Bat)	Chuckwalla	Slickrock Desert-parsley
Small-footed Myotis (Bat)	Arizona Southwestern Toad	Jane's Globe-mallow
Yuma Myotis (Bat)	Roundtail Chub	Copper Canyon Milkvetch
Southwestern Otter	Flannelmouth Sucker	Cronquist Milkvetch
La Sal Pika	Great Basin Silverspot Butterfly	Alcove Rock-daisy
Navaho Mountain Mexican Vole	Yavapai Mountain Snail	*Penstamon crandallii* var. *atratus*
North American Wolverine		*Psorothamnus thompsonae* var. *whitingii*

State of Utah-listed Sensitive Species		
Abert's Squirrel	Western Bluebird	Glossy Snake
Mountain Bluebird	Desert Night Lizard	Utah Milksnake

3.6 Air Investigations

3.6.1 Summary of Air Investigations

DOE established monitoring programs for atmospheric radon, air particulates, direct gamma radiation, and meteorology to define an air-quality baseline for the millsite and vicinity, and to verify compliance with Federal ambient air-quality and radiation-protection standards and DOE orders for radiation protection of the public. Upon remediation of the millsite, the monitoring strategy will change from environmental surveillance mode to effluent monitoring. The locations

of background monitoring stations for all components of the air monitoring programs are being reevaluated by DOE and EPA, with resolution expected during 1995. Although the monitoring programs focus on millsite conditions, some off-site monitoring results apply to OU III as well.

3.6.2 Atmospheric Radon Monitoring

Radon monitoring began in 1983 with the installation of monitors at 19 locations. After one year of collecting baseline data, the monitoring network was reduced to 8 representative locations. However, 7 more locations were added during the third quarter of 1993 in response to increasing levels of remedial construction. All monitoring stations were installed at a height of about 1 meter above the ground surface. Atmospheric radon concentrations measured between 1983 and 1993 consistently exceeded the EPA standard at every on-site and edge-of-boundary location, as well as at one off-site location about one-third mile east of the millsite on the Montezuma Creek floodplain.

Two real-time radon monitors were installed downwind (northeast and east) of the millsite in 1992 to monitor the effect increased construction activity at the millsite on ambient radon concentrations. The monitoring data do not show increases in radon emissions in that time. Rose diagrams of prevailing wind trends and annual average wind magnitudes for the millsite weather station data are shown in Figures B–2 and B–3, respectively.

3.6.3 Air Particulate Monitoring

Monitoring of air particulates began in August 1983 using three high-volume air samplers located along the two predominant wind directions (east and north) and at a background site. In March 1987, 10-micron selective inlets were installed in the samplers to allow only the respirable and biologically damaging particles to be collected. This change allowed direct measurement of the mass concentration of total suspended airborne particulate matter having nominal aerodynamic diameters less than 10 microns (PM_{10}). In November 1993, seven low-volume radioparticulate samplers and two PM_{10} samplers were installed adjacent to the millsite and the City of Monticello in response to an increase in remedial activities. After addition of the low-volume radioparticulate samplers network, the five high-volume samplers were used for sampling nonradiological PM_{10} only. All measured radiological concentrations (total uranium, radium–226, and thorium–230) have consistently been well below their respective derived concentration guidelines (DCGs). Nonradiological concentrations of PM_{10} and lead (monitored from 1983 through 1991) also were consistently within their respective compliance levels.

3.6.4 Direct Gamma Radiation Monitoring

A direct environmental radiation monitoring program was initiated at the MMTS in April 1991 to assess the potential gamma radiation dose to persons on or near the millsite. Radiation measurements collected at 13 monitoring locations on the millsite and surrounding areas were monitored quarterly. In the fourth quarter of 1993, seven monitoring locations were added to the sampling network to further define the off-site gamma dose. Only on-site locations yielded annual

average measurements greater than the DOE standard of 100 millirem (mrem) per year; annual averages of measurements collected off site have consistently been below the DOE standard.

3.6.5 Meteorological Data Recording

Meteorological conditions are monitored at the millsite for use in dose modeling. A data-gathering station installed in 1982, initially recorded temperature, relative humidity, wind direction and velocity, and barometric pressure. The station was upgraded in 1991 in response to DOE performance standards for meteorological monitoring equipment. However, data collection did not resume until November 1993 because of administrative and technical problems.

3.7 Off-site Dose Monitoring

Before 1993, site-specific data collected between 1981 and 1987 were used in off-site dose models to calculate collective population dose commitments caused by radon emissions from the millsite. The *RI/FS—EA* (DOE 1990b) lists the source terms calculated for the exposure rates, air-particulate concentrations, radon emissions, and models used to estimate the dose equivalents received by Monticello residents. In 1993, dose assessment modeling predicted a collected radon dose of 22 person-rem per year to individuals living within 80 kilometers of the millsite.

Monitoring data collected since 1981 for air particulates, radon, and gamma radiation, along with a radon source term derived from predicted atmospheric radon concentrations (DOE 1990a), have been used to calculate the annual effective dose equivalent (EDE) to a maximally exposed off-site individual living near the millsite. The calculated EDE has consistently been below the DOE standard of 100 mrem per year above background.

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4.0 Remedial Investigation

The OU III RI is being conducted in accordance with *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), *Data Quality Objectives Process for Superfund* (EPA 1993b) and guidance specified in the NCP (40 CFR Part 300). These guidance documents are being used to ensure that the RI is implemented in a manner consistent with established EPA protocol and that the type, quality, and quantity of data collected will be sufficient to support informed and defensible risk management decisions. As discussed in Section 1.2, the OU III RI focuses on development of a baseline risk assessment, the results of which will be used to support remediation decisions regarding the sediment/soil and surface water/ground-water contaminant sources within OU III (Figure 1.2-2).

The OU III RI has three main goals: (1) obtain the information necessary to assess ecological and human health risks are posed by the sediment/soil contaminant source in the focused study area, (2) obtain the information necessary to assess ecological and human health risks posed by the surface water/ground-water contaminant source within OU III, and (3) collect sufficient quality data to support evaluation of any appropriate response actions, if required. A baseline risk assessment will serve as the mechanism for accomplishing these goals. The baseline risk assessment will be supported by existing site data (where appropriate), new data collected during focused field investigations, and ground-water flow and transport model results. OU III risk assessment studies, as well as ground-water modeling, will also be supported by information generated through continuation of the OU III annual surface water and ground-water monitoring effort.

The scope of the OU III RI consists of the following eight tasks:

- Task 1: Project Planning
- Task 2: Community Relations
- Task 3: Baseline Characterization
- Task 4: Ecological Risk Assessment
- Task 5: Human Health Risk Assessment
- Task 6: Ground-Water Modeling
- Task 7: Annual Monitoring
- Task 8: RI Report

The remainder of this section contains a description of the DQO process, including how the process was implemented for OU III, followed by separate discussions of each of the RI tasks listed above.

4.1 Data Quality Objective Process

EPA developed the DQO process to ensure that data collected as part of remedial response activities are adequate for and are an integral part of decision making. The DQO process is a means of employing scientific methods in the development of data collection designs. The

process involves (1) clarifying study objectives, (2) defining the most appropriate types of data to collect, (3) determining the most appropriate conditions from which to collect the data (e.g., spatial, temporal), and (4) specifying acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision (EPA 1993b).

According to *Data Quality Objectives Process for Superfund* (EPA 1993b), the purpose of the DQO process is to " . . . collect data of appropriate quality for environmental decisions while minimizing expenditures related to data collection by eliminating unnecessary duplication of overly precise data." The DQO process, which is iterative in nature, is a management planning tool available to help decide what type, quality, and quantity of data will be sufficient to make identified environmental management decisions. The DQO process requires that these decisions, and the qualitative or quantitative criteria upon which decision making is based, are stated in advance of data collection activities.

Data Quality Objectives Process for Superfund (EPA 1993b) was used as a guide to formulate the general objectives of the RI into specific decisions, identify RI data requirements, design appropriate data collection efforts, and assess decision making confidence as it relates to decision error. In particular, decision error can have a major impact on risk management issues and the selection of the appropriate response actions. Decision error relates to the consequences of making an incorrect decision. For example, if the decision criteria corresponds to the low end of the risk range (10E-4 cancer risk) and the estimated risk is 10E-5, the estimated risk can be incorrect by up to one order of magnitude without resulting in an adverse impact or "incorrect" decision.

The DQO process is initially applied to the general RI data requirements and the overall decisions to be made on the basis of the RI data. Table 4.1-1 provides an overview of the DQO process and illustrates how the process is used to support identification of general data requirements and decisions for the OU III RI. The DQO process is then applied separately to (1) the ecological risk assessment, (2) the human health risk assessment, and (3) the ground-water modeling effort because each of these assessments has different data needs and will be used to address different decisions. The DQO process for the ecological and human health risk assessments is implemented separately for each medium of concern (i.e., shallow ground water, surface water, sediment, soil, and biota). Specific application of the DQO process for the ecological risk assessment, human health risk assessment, and ground-water modeling effort is discussed in Sections 4.5.4, 4.6.4.1 and 4.7.1 respectively.

Step 3 of the DQO process (identify inputs to the decision) warrants further discussion. The primary inputs to the OU III decision-making process include the ecological and human health risk assessments, ground-water modeling, and existing rules and regulations. Risk assessments and ground-water modeling are in turn supported by data generated through collection and analysis of existing and new information. Therefore, Step 3 of the DQO process also involves determining the extent to which existing data can be used to support the risk assessment studies and ground-water modeling.

Table 4.1-1. DQO Process

Step No.	Step Title[a]	Purpose[a]	Operable Unit III Process/Status
1	State the Problem	• Summarize the problem that will require new environmental data. • Identify resources available to resolve the problem.	• Preliminary conceptual site models have been developed. (See Sections 4.5.3.1 and 4.6.1) • Project objectives are presented in Section 1. • ETAG will serve as the scoping team.
2	Identify the Decision	• Identify the decisions that require new environmental data.	• Assess if chemical concentrations are site related. • Determine if elevated concentrations present risk to human or ecological receptors. • Estimate if COC concentrations exceed ARARs. • Estimate time required for ground and surface water to reach acceptable regulatory and risk-based levels. • Specific decisions for the ecological and human health are presented in Sections 4.5.4 and 4.6.4.
3	Identify the Inputs to the Decision	• The information needed to support the decision and specify which inputs require new measurements.	• Existing monitoring data for ground water, surface water, sediments, air, and soil. • Preliminary ecological and human health risk calculations based on available data. • Assessment and measurement endpoints as outlined by the ETAG and presented in the ecological concept paper. (See Section 4.5.3.2) • Ecological survey data on Montezuma Canyon. • Background data from Verdure Creek Canyon.
4	Define the Study Boundaries	• Specify the spatial and temporal aspects of the environment that the data must represent to support the decision.	• Specifics to gathering additional data depend on its use. Data will be used to support the ecological and human health risk assessments and the ground-water modeling. See the following sections for more information: - Ecological Risk - See Section 4.5.4 - Human Health Risk - See Section 4.6.4 - Ground-Water Modeling - See Section 4.7.5
5	Develop a Decision Plan	• Statements that define the conditions that would cause the decision maker to choose among alternatives.	• Figure 1.2-2 shows the logical decision process for this project. Preliminary ecological risk decisions will be based on a Hazard Quotient of 1 and benchmarks found in the literature. For human health, guidelines specified in the NCP were used: $1x10^{-4}$ to $1x10^{-6}$ for carcinogens and a Hazard Quotient of 1 for noncarcinogens.
6	Specify Limits on Decision Errors	• Specifies the decision maker's acceptable limits on decision errors.	• The BRA will contain an uncertainties section which discusses relative errors associated with the risk assessment results.
7	Optimize the Design for Obtaining Data	• Identifies the most resource effective sampling and analysis design for generating data that are expected to satisfy DQOs.	• Limited additional sampling will be done in seven areas. A total of 228 samples will be gathered. Details are provided in Sections 4.5.4 and 4.6.4.

[a]From *Data Quality Objective for Superfund* (EPA 1993a).

A general description of how existing data were reviewed with respect to the OU III risk assessments and ground-water modeling is provided below.

- Have all geographic areas where water quality and sediment/soil could be affected been assessed?

  Geographically, water quality samples have been collected for radiological, metals, and organic analyses throughout OU III as well as both upgradient and downgradient of OU III. However, water quality samples have not been collected in the reference area established for OU III. Sediment/soil samples have been collected at the millsite and along Upper and Lower Montezuma Creek. However, sediment/soil samples have primarily been analyzed for radiological constituents and only a few samples have been analyzed for metals. In addition, no sediment/soil samples have been collected in the reference area established for OU III.

- Do the data provide information on variability within and between seasons, years, and precipitation events?

  No established monitoring program, using consistent monitoring locations, was implemented at the MMTS before 1992. Monitoring under the OU III RI was initiated in September 1992 with implementation of the Baseline Characterization. The Baseline Characterization continued through July 1993. Under the Baseline Characterization, ground-water levels and stream flow measurements were collected on a monthly basis, and surface water and ground-water samples were collected on a quarterly basis. The Annual Monitoring Program was implemented upon completion of the Baseline Characterization in July 1993 and will continue at least through completion of the ROD. Under the Annual Monitoring Program, monthly ground-water level and stream flow measurements have continued, and surface water and ground-water samples have been collected on a semiannual basis (during the months when water levels are typically at the lowest and highest elevations).

  Except for monthly water level and stream flow measurements, no data have been collected specifically to assess variability within seasons or between precipitation events. However, precipitation data obtained from the National Weather Service monitoring station located in Monticello will be used in conjunction with monthly water level and stream flow measurements to assess the variability associated with major precipitation events. These assessments will be performed as part of the ground-water modeling effort.

- Are the number of samples/locations sufficient to assess variability to an acceptable level?

  Variability within surface water and ground water can be sufficiently assessed on the basis of data collected during the OU III Baseline Characterization and Annual Monitoring Program. The monitoring networks and analytical programs for the Baseline

Characterization and for the Annual Monitoring Program were designed to provide the detail necessary to adequately assess the nature and extent of contamination in surface water and ground water within OU III and the surrounding area.

The number and location of sediment/soil samples previously collected do not provide the information to sufficiently assess variability within these media. Specifically, additional analytical data for sediment/soil are needed within the focused study area of OU III.

The number and location of air samples collected within OU III and the surrounding area are sufficient to assess variability within air. Air monitoring data have been collected on a weekly basis since 1993 at 10 monitoring stations encircling the millsite and 2 monitoring stations located approximately 5 miles north of the millsite.

No analytical data have been generated for biotic media within OU III. Therefore, additional data will be required to assess variability within this medium.

- Are the quality and quantity of data sufficient to support the risk assessments and ground-water modeling and to determine compliance with reference criteria?

  In general, surface water and ground-water data collected under the OU III RI (beginning in 1992 with data collected for the Baseline Characterization) are considered to be of higher quality than data collected before the RI. Field and laboratory documentation for data collected under the RI are sufficient to allow assessment of data quality. However, the quality of previous RI data has not been fully assessed. Therefore, data quality assessments will be completed for all previous and new RI data to be used in support of the risk assessment studies.

  Field and laboratory documentation are limited for surface water and ground-water data collected before initiation of the RI. Prior to 1984, the documentation required to support assessment of data quality was not maintained. Between 1984 and 1992, sufficient analytical records were maintained but equivalent field documentation was not maintained. Therefore, surface water and ground-water data obtained before the RI was initiated will not be used to quantitatively support the risk assessments.

  Existing analytical data for sediment/soil are not of sufficient quality or quantity to fully support the human health and ecological risk assessments and ground-water modeling. Additional sediment/soil sampling locations, collocated with other abiotic and biotic sampling locations, are needed both on site and in the reference area.

  Analytical data for biotic media are needed to support the ecological and human health risk assessments. For the ecological risk assessment, biotic samples, collocated with abiotic media samples, are needed both on site and in the reference area.

Existing hydrogeologic data, coupled with data obtained from literature, are of sufficient quality and quantity to support ground-water modeling. These data will be used as input to the model. In general, literature values will be used to estimate input parameters such as distribution coefficient, storage coefficients for bedrock, recharge, evapotranspiration, and dispersivity. Other input parameters (e.g., water level elevations and hydraulic conductivity) will be estimated from existing site data.

- Are detection limits associated with the data sufficient for the risk assessments?

  Except for silver, mercury, beryllium, arsenic, and Pb-210, the detection limits associated with previous RI data are sufficient for the risk assessments. Of the analytes listed, silver, mercury, and beryllium are not expected to be contaminants related to the uranium-vanadium ore that was processed at the MMTS or expected to have been introduced during MMTS operations. The detection limits for arsenic and lead-210 are within the 10E-4 to 10E-6 cancer risk range for these analytes under a residential use scenario.

- Do the data meet the requirements of representativeness, precision, and accuracy for risk assessment?

  Existing RI data have not been fully reviewed for representative, precision, and accuracy. However, all case narratives have been reviewed and indicate that few analytical results exceed precision and accuracy criteria. All new and existing RI data will be fully reviewed with respect to these criteria before being used to support the risk assessments.

4.2 Task 1: Project Planning

Project planning for the OU III RI/FS began in 1992, with preparation of the *Surface and Ground-Water Remedial Investigation/Feasibility Study—Work Plan* (DOE 1992c). The purpose of the 1992 Work Plan was to outline the monitoring program designed to characterize baseline surface water and ground-water conditions within OU III. This program is referred to as the baseline characterization and is identified as Task 3 in this Work Plan. Results of the baseline characterization are summarized in Section 4.4 and documented in the *Monticello Mill Tailings Site, Operable Unit III, Baseline Characterization Data Summary* (DOE 1994b). Surface water and ground-water monitoring has continued subsequently to the baseline characterization under the OU III annual monitoring program. The annual monitoring program has been conducted in accordance with the scope of work and procedures outlined in the 1992 Work Plan, as amended. DOE-, EPA-, and State-approved amendments to the original scope of work and/or procedures presented in the 1992 Work Plan have been documented in Program Directives. Continuation of the annual monitoring program (Task 7) is discussed in Section 4.8.

At the time the 1992 Work Plan was prepared, it was anticipated that a separate work plan would be prepared to address the sediment and soil component of OU III and that the 1992 Work Plan would be revised to support post-baseline characterization activities for the surface water and ground-water component of OU III. However, after the baseline characterization

was completed, DOE, EPA, and the State agreed that a single RI/FS Work Plan should be prepared to address both components of OU III. Integration of the two components is being accomplished with this Work Plan.

The following OU III planning documents accompany this Work Plan:

Operable Unit III Remedial Investigation/Feasibility Study, Field Sampling Plan: The Field Sampling Plan (FSP) provides detailed descriptions of field procedures and lists the laboratory methods to be used for sample analysis. The plan describes field activities and identifies proposed sampling locations. In addition, the FSP specifies the number and types of samples and measurements required, use of sample identification numbers, analytical parameters, and field quality assurance and quality control (QA/QC) measurement requirements.

Operable Unit III Remedial Investigation/Feasibility Study, Quality Assurance Project Plan: The Quality Assurance Project Plan (QAPjP) describes the methods and procedures that will be used to verify the precision, accuracy, and completeness of the data generated during the RI/FS. The QAPjP addresses the requirements set forth in the *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations* (EPA 1993d).

All field activities conducted in support of the OU III RI/FS will be performed in accordance with the health and safety requirements specified in the *Monticello Projects Health and Safety Plan* (DOE 1995a).

4.2.1 Technical Approach

The technical approach for the OU III RI/FS is to assess ecological and human health risks posed by COPCs within the OU III study area such that defensible response action decisions can be made on the basis of RI/FS results. The steps followed to formulate the approach are discussed below.

Step 1: Identification of Primary Decisions

The first step taken to develop the approach was to identify primary decision points to be reached during the RI/FS. Ultimately, RI/FS results will be used to determine if remediation of contaminant sources within OU III is necessary, and if so, what response actions are appropriate. Potential contaminant sources within OU III include sediment and soil within the focused study area and surface water and ground water at and downgradient of the millsite. The primary decisions to be reached during the RI/FS are:

- The first decision, to be made during the RI, will be whether or not there is an unacceptable current or future risk to human health or the environment.

- The second decision, to be made during the RI (assuming unacceptable risk), is if an early action is warranted. Any early action would have to support a final remedy and meet proposed ARARs. The decision to proceed with an early action is based on unacceptable risk and Engineering Evaluation/Cost Analysis (EE/CA).

- The third decision, to be made during the FS, will be whether or not the final remedy can meet ARARs.

- If, as part of the third decision, it is determined that ARARs cannot be practicably met, the fourth decision will be whether or not some alternative remedy requirements (other than ARAR waivers) are appropriate. If no other alternative remedy requirements are appropriate, ARAR waivers will be pursured.

Step 2: Generate a Preliminary List of ARARs

The second step taken to develop a technical approach was to generate a preliminary list of ARARs. The list was developed by using the ARARs specified in the 1990 Record of Decision (ROD) for OUs I and II of the MMTS, then modifying the list for ARARs considered pertinent to OU III. The resulting preliminary list of ARARs is presented in Appendix A.

3: Review Decision-Making Process

After a preliminary list of ARARs was generated, the next step was to review the decision-making process for OU III and to determine how decisions will impact subsequent OU III activities. In accordance with CERCLA, the baseline risk assessment will be used to support decisions regarding the acceptability and management of risks associated with sediment/soil and surface water/ground-water contaminant sources within OU III.

Sediment and Soil Contaminant Source

If cumulative risks are not acceptable for COPC within the focused study area, the baseline risk assessment and ground-water modeling results will be used to assess whether the unacceptable risks are due to contaminant transport from the sediment/soil contaminant source or from surface water and/or effluent ground-water contamination attributed directly to the millsite.

Unacceptable risks attributed exclusively to millsite-derived surface water or ground-water contamination will be evaluated under the surface water and ground-water component of OU III; therefore, no further action relative to the sediment/soil contaminant source will be required. The no-further-action decision will be presented in the Proposed Plan. If necessary, the decision will be supported by application of ARAR waivers.

If risks are attributable to sediment/soil, ARAR waivers (i.e., supplemental standards) will be evaluated during preparation of the draft FS report. The ARAR waiver evaluation will provide the basis for determining the response action required, if any. If the RPMs find that removal is

warranted, the removal action process will be implemented. If the RPMs find that other response actions may be more appropriate, an alternative will be selected from those screened and evaluated in the FS. The selected alternative will be documented in the Proposed Plan and ROD.

Removal action(s) will be implemented in accordance with the requirements established under CERCLA. A removal site evaluation will be prepared to support the RPM's determination regarding the appropriateness of removal action(s). In addition, an engineering evaluation/cost analysis (EE/CA) will be prepared to document the analysis of removal alternatives. Removal alternatives will be consistent with the alternatives implemented for OUs I and II. It is critical that any removal actions be completed by the November 1998 closure date of the on-site millsite tailings repository to minimize disposal cost and community impacts associated with transport to an off-site repository

Surface Water and Ground-Water Contaminant Source

If current exposure-point concentrations are not found to be protective of human health and the environment, response action alternatives will be screened and evaluated in the FS. As required under CERCLA, the no-action alternative will be included as a baseline against which protectiveness, cost, and other criteria can be measured. Evaluation of the no-action alternative will include assessment of ground-water model predictions regarding the length of time anticipated for exposure-point concentrations to attain levels protective of human health and the environment and meet other reference criteria (statutory federal drinking water maximum contaminant levels [MCLs], ARARs, background concentrations, risk-based concentrations and other "to be considered" [TBC] criteria). An example of a particular land use requiring evaluation of a distinct suite of exposure point concentrations would be a residence occupied adjacent to the floodplain along upper Montezuma Creek. If it is determined that exposure-point concentrations will attain such levels in a reasonable period of time, the Proposed Plan and ROD will document that no remedial action is warranted. The no-remedial-action decision will be verified through continued monitoring for a specified period of time.

During the RI, DOE will establish a period of time considered reasonable in conjunction with the EPA and State. Reasonable time will be determined on the basis of current and potential future land uses along upper and lower Montezuma Creek, point (s) of compliance, contaminant-specific cleanup criteria (ARARs, risk, etc.), and exposure-point concentrations. The availability and adequacy of alternative control measures such as institutional controls will also be considered during development of reasonable time. The reasonable times for both surface soil/sediment and ground water/surface water in both the upper and lower reaches of OU III will be used to evaluate remedial alternatives.

Step 4: Review Existing Site Knowledge

The fourth step in development of the approach was to review existing site knowledge in relation to the primary decisions identified in Step 1. Initially, existing data were reviewed and evaluated to assess the adequacy of the data for risk assessment studies. The data were reviewed with respect to instrument detection limits, spatial distribution and number of samples, and period of record. Reviewed data were then used to perform preliminary site calculations for the ecological

and human health risk assessments. These calculations were made based on the assumption that residential land use will likely occur in Upper Montezuma Creek but not in Lower Montezuma Creek. Preliminary site calculations for the ecological and human health risk assessments are further discussed in Sections 4.5.2 and 4.6.3, respectively.

Step 5: Design Implementation Process

The final step taken to develop an approach was to design a process for implementation of the RI/FS. The process was designed based on the outcomes of each of the preceding steps, communications with EPA and the State, and regulatory guidance.

Specific technical approaches for the ecological and human health risk assessment tasks were formulated in accordance with existing EPA guidance, including *Framework for Ecological Risk Assessment* (EPA 1992a), *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual*, (EPA 1989d), *Guidance for Data Useability in Risk Assessment*, (EPA 1992b), and specific guidance documents developed by EPA Region 8. The technical approach for the ecological risk assessment contains the following primary elements:

- Preliminary Problem Formulation and Ecological Effects Evaluation
- Preliminary Exposure Estimates and Risk Calculation
- Problem Formulation: Assessment Endpoint Selection and Testable Hypothesis Formulation
- Site Assessment
- Site Field Investigation
- Risk Characterization
- Risk Management

The first three elements listed above were completed during the preparation of this plan and are discussed in Sections 4.5.1 through 4.5.3. Site assessment and site field investigation are discussed in Section 4.5.4. The risk characterization element is discussed in Section 4.5.5.

The major elements included in the technical approach for the human health risk assessment are discussed in Section 4.6.2 and include:

- Data Evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

Both the ecological risk assessment and the human health risk assessment will be supported by ground-water flow and transport modeling. The model will be used as a tool to predict future concentrations of select COPC in ground water at the end of specific time intervals (e.g., 10, 20, and 70 years) after completion of millsite remediation. Modeling results will also be used to estimate concentrations of select COPC in surface water at specific locations and times. Modeling will be accomplished through development and application of a MODFLOW/MT3D ground-water flow and transport model being developed in close cooperation with EPA experts. The ground-water modeling task is further discussed in Section 4.7.

The last component of the OU III technical approach involves the annual monitoring task for surface water and ground water (Section 4.8). The annual monitoring task was initiated in 1992 and will continue at least through completion of the OU III Proposed Plan and ROD for surface water and ground water. The existing ROD for the MMTS requires continued monitoring of surface water and ground water for three years after remediation of OUs I and II. Annual monitoring results will be used to support OU III risk assessment studies and the ground water modeling effort as well as to provide a continuous record of surface water and ground water conditions over time. Under the annual monitoring task, ground-water levels and stream flow measurements will be recorded on a monthly basis, and surface water and ground-water samples will be collected for chemical analysis on a semiannual basis.

All site characterization activities for the OU III RI/FS will be performed in accordance with the procedures and guidelines presented in the accompanying Field Sampling Plan. The procedures and guidelines are designed to ensure the data are defensible and that disruption of the environment/ecosystems is minimized.

4.3 Task 2: Community Relations

Community Relations activities for OU III are included in the draft final Community Relations Plan Update (currently draft final July 1995, DOE 1995b), which is currently being reviewed by EPA and the State of Utah. The Community Relations Plan update incorporates community relations activities for MMTS, Monticello Vicinity Properties, and Monticello Surface Water and Ground Water remedial action projects. Near-term public involvement activities include development of Fact Sheets on OU III, issuance of a news release and display ad on completion of the RI/FS Work Plan, and coordination of public meetings regarding the final RI/FS Work Plan and the draft final Proposed Plan. Specific activities to be performed through 1998 can be found in the draft final Community Relations Plan Update.

4.4 Task 3: Baseline Characterization

4.4.1 Objectives

The objective of the OU III baseline characterization was to collect data necessary to adequately characterize baseline ground-water and surface water conditions at and in the

vicinity of the MMTS. For RI/FS purposes, baseline conditions refer to ground-water and surface water conditions existing before implementation of significant millsite remedial action activities.

The ground-water component of the characterization focused on baseline conditions present in the upper flow system, water-bearing sandstone units in the lower Dakota Sandstone, and the Burro Canyon aquifer. Within these systems, information was obtained to assess water-quality conditions in upgradient (background) and downgradient areas. Information also was obtained to assess water quality conditions in the upper flow system at the millsite. Water quality information was used to further assess the nature and extent of contamination. This information has been used to establish a list of COPCs and, by comparison to toxicity benchmark values to verify that laboratory detection limits are adequate (Appendix C). In addition to water quality information, water level measurements were taken to assess ground-water flow directions and gradients associated with each of the ground-water systems, as well as the degree of hydrologic communication existing between the lower Dakota Sandstone and the Burro Canyon aquifer.

The surface water component of the characterization focused on baseline water quality conditions in upstream (background), millsite, and downstream areas. In addition, stream flow measurements obtained along Montezuma Creek were used to assess ground -water/ surface water interactions.

4.4.2 Scope of Work

Work performed in support of the baseline characterization was accomplished in accordance with the scope of work and procedures outlined in the *Monticello Mill Tailings Site, Operable Unit III, Surface and Ground-Water Remedial Investigation/ Feasibility Study Work Plan* (DOE 1992d), *Field Sampling Plan* (DOE 1992b), and *Quality Assurance Project Plan* (DOE 1992c). Scope of work or field procedure variances made during implementation of the baseline characterization effort are discussed in the *Baseline Data Summary Report* (DOE 1994b).

4.4.2.1 Field Program

The field program for the baseline characterization was initiated in September 1992 and completed in October 1993. The program consisted of the following components:

- Installation of 13 monitoring wells, 9 piezometers, and 15 soil borings.
- Measurement of water levels in approximately 83 monitoring wells on a monthly basis.
- Collection of ground-water samples at 27 monitoring wells during 4 separate sampling events.
- Collection of surface water samples at 16 sites during 4 separate sampling events.

- Measurement of stream flow at 12 sites along Montezuma Creek.

Locations of the monitoring wells, piezometers, and surface water sites included in the characterization are shown on Plate 4-1.

The monitoring wells and piezometers installed during baseline characterization are located upgradient and downgradient of the millsite; no new wells or piezometers were located within the boundaries of the millsite. Seven wells were installed upgradient of the millsite, including three wells completed in the upper ground-water flow system, one well completed in the lower Dakota Sandstone, and three wells completed in the Burro Canyon aquifer. Six monitoring wells were installed downgradient of the millsite, including four wells completed in the upper ground-water flow system, one well completed in the lower Dakota Sandstone, and one well completed in the Burro Canyon aquifer. All nine of the piezometers were installed downgradient of the millsite and completed in the upper ground-water flow system. Fifteen soil borings were also drilled downgradient of the millsite; each borehole extended to the bedrock contact.

During drilling of the bedrock wells, 8 core samples were collected from the Dakota Sandstone and 8 core samples were collected from the Burro Canyon Formation for vertical conductivity analysis. All cores were tested in triaxial cells under two gradients; a summary of the results is presented in Table 4.4-1.

Table 4.4-1. Summary of Vertical Hydraulic Conductivity Testing

	Burro Canyon Formation	Upper Dakota Sandstone	Lower Dakota Sandstone
K_v[a] - maximum	7.1×10^{-4} cm/sec	1.0×10^{-8} cm/sec	7.2×10^{-9} cm/sec
K_v - minimum	8.1×10^{-10} cm/sec	1.8×10^{-10} cm/sec	2.4×10^{-11} cm/sec
Arithmetic mean	1.3×10^{-4} cm/sec	2.3×10^{-9} cm/sec	2.1×10^{-9} cm/sec
Standard deviation	2.0×10^{-4} cm/sec	3.9×10^{-9} cm/sec	2.1×10^{-9} cm/sec
Coefficient of variation	150	170	100
Geometric mean	4.7×10^{-6} cm/sec	1.2×10^{-9} cm/sec	9.5×10^{-10} cm/sec

[a] K_v = Vertical Hydraulic Conductivity

The water-level survey was performed to measure water levels in monitoring wells completed within the upper ground-water system, lower Dakota Sandstone, and Burro Canyon aquifer. The objective of the survey was to obtain monthly, comprehensive, and concurrent sets of water-level measurements during a one-year period. Water levels were generally measured on a monthly basis in approximately 83 monitoring wells.

Ground-water samples were collected during four sample events — November/December 1992, March 1993, April/May 1993, and July 1993. The monitoring-well network consisted of 16 wells completed in the upper ground-water flow system, 2 wells completed in the lower Dakota Sandstone, 1well completed across the Dakota Sandstone/Burro Canyon Formation contact, and eight wells completed in the Burro Canyon aquifer. Most wells were purged and sampled with a dedicated bladder type of pump. A Teflon bailer was used to purge and sample wells that dewatered completely during purging. Field parameters were measured at each well during purging and immediately before sample collection to ensure that ground water conditions were stabilized. Field parameter measurements included temperature, pH, electrical conductivity, alkalinity, dissolved oxygen, oxidation-reduction potential, and turbidity. Dissolved oxygen and oxidation-reduction potential were not measured in wells that were bailed. Field analysis for residual chlorine was performed for each well only during the November/December 1992 sampling event.

Surface water samples were collected during the four ground-water sampling events (November/December 1992, March 1993, April/May 1993, and July 1993). The surface water sampling network consists of 16 locations, including 3 sites located upgradient of the millsite, 6 sites located within the boundaries of the millsite, and 7 sites located downgradient of the millsite. Samples were collected at each of the sampling sites unless a particular site was inaccessible, dry, or frozen. Field parameters were measured at each sampling site immediately before sample collection. Field parameter measurements included temperature, pH, electrical conductivity, and alkalinity. Field analysis for residual chlorine was performed at each site only during the November/December 1992 sampling event.

Surface water flow measurements were obtained to assess stream discharge rates along Montezuma Creek. Measurements were obtained at the 12 surface water sampling sites established along Montezuma Creek. Measurements were acquired during a 10-month period beginning in December 1992 and extending through September 1993. Flow measurements were not obtained at some of the sampling sites because of unfavorable site conditions (e.g., frozen or dry), variable releases of water from Loyd's Lake (located upgradient of the millsite), or an instrument malfunction.

Duplicate samples were collected during each ground-water and surface water sampling event at a frequency of one for every ten samples collected.

4.4.2.2 Analytical Program

All water samples collected for the baseline characterization were submitted to the Grand Junction Projects Office (GJPO) Analytical Laboratory for analysis. The *Field Sampling Plan* (DOE 1992b) contains laboratory requirements for sample containers, sample volume, preservation, holding times, and analytical methods. The QAPjP (DOE 1992c) specifies analytical methods for each analyte and associated LRLs. The GJPO Analytical Laboratory's LRLs are EPA's Contract Laboratory Program (CLP) CRDLs for inorganic analytes; the actual GJPO Analytical Laboratory detection limits for inorganics generally run an order of magnitude less than the CRDLs. For organic compounds, the GJPO Analytical Laboratory

LRL is equal to one-half the CLP Contract Required Quantitation Limits (CRQL) for TCL volatile organic compounds (VOCs) and equal to the CRQL for TCL Semi-VOCs, TCL pesticides/PCBs and herbicides. Data tables reported in the *Baseline Characterization Data Summary Report* (DOE 1994b) include the quarterly-updated GJPO instrument detection limits whenever an inorganic analyte is not detected and qualify organic compounds as estimated if they are detected below the quantitation limit.

The analyte groups constituting the analytical program included radiological constituents, metals, TCL VOCs, TCL semi-VOCs, and TCL pesticides/PCBs, and herbicides. Organic compound analyses were performed only on samples collected from selected wells during selected sampling events. All samples were analyzed by GJPO standard operating procedures for EPA methods.

Quality assurance measures performed during laboratory analyses included calibrations of laboratory equipment and internal laboratory quality-control checks (e.g., reagent blanks, duplicates, matrix spikes, matrix spike duplicates).

4.4.3 Summary of Results

A general summary of ground-water and surface water sampling results is provided below. Baseline characterization results are discussed in greater detail in the *Baseline Characterization Data Summary* (DOE 1994b).

4.4.3.1 Upper Ground-Water Flow System

Baseline characterization results indicate that radiological and metals analytes are the most commonly occurring preliminary contaminants of concern in upper flow-system ground water at and in the vicinity of the MMTS. During the baseline characterization, the only TCL VOCs and TCL semi-VOCs detected at concentrations above LRLs were methylene chloride and bis-(2-ethylhexyl)phthalate, both of which are commonly observed as laboratory contaminants. Toluene was reported at the LRL of 1.1 μg/L in one sample collected during the baseline characterization. No TCL pesticides/PCBs or herbicides were detected above LRLs in samples collected during the baseline characterization.

Maximum radiological and metals analyte activities/concentrations, excluding anomalous results, reported during the baseline characterization for samples from wells completed in the upper ground-water flow system are presented in Tables 4.4-2 and 4.4-3, respectively. Anomalous results include qualified results and results for samples with high turbidity. As shown, concentrations are typically lowest in the upgradient area and highest at the millsite. In the downgradient area, concentrations generally decrease with increasing distance from the millsite.

Common ion data obtained during the baseline characterization indicate that no dominant cation-anion pair characterizes the upper flow system on a site-wide basis. Upgradient of the millsite, calcium is the dominant cation and sulfate and bicarbonate are the dominant anions.

Table 4.4-2. Maximum Radiological Analyte Activities (in pCi/L), Excluding Anomalous Results, Detected in the Upper Ground-Water Flow System During the Baseline Characterization

Analyte	Upgradient	Millsite	Downgradient
Gross Alpha	<12 -<50	5,100	2,300
Gross Beta	<7-<52	1,500	1,000
Pb-210	<2	55	18
Po-210	<0.10-<1.01	2.6	0.72[a]
Ra-226	0.4	12	6.9
Ra-228	<1-<2	<1-<7	<1-<7
Rn-222	1,300	29,000	11,000
Th-230	0.45	1.0	0.92
Th-232	0.55	0.88	<0.06-<0.30
U	6.2[a,b]	4,400[b]	2,900[b]
U-234	5[a]	1,400	970
U-235	0.49	190	51
U-238	2.3[a]	1,400	990

[a]An activity/concentration greater than the value shown was reported but is considered anomalous due to high turbidity.
[b]Analytical result reported in micrograms per liter (μg/L).

Table 4.4-3. Maximum Metals Concentrations (in μg/L), Excluding Anomalous Results, Detected in the Upper Ground-Water Flow System During the Baseline Characterization

Analyte[a]	Upgradient	Millsite	Downgradient
Aluminum	410[b]	340[b]	150[b]
Arsenic	3.6	166	34[b]
Boron	67[b]	260	540
Iron	700[b]	5,140[b]	1,300[b]
Lead	1.6	19.2[b]	<1.0-2.2[b]
Manganese	3.0[b]	12,000[b]	1,900[b]
Molybdenum	3.0	550[b]	200
Selenium	5.1	24[b]	57
Strontium	3,600[b]	4,700	4,700
Vanadium	<4-<8	2,900	890[b]
Zinc	41	27[b]	<3.0-17

[a]Does not include analytes that either were not detected at concentrations above LRLs or detected at concentrations above LRLs, but the results are considered anomalous because of high turbidity or analytical qualifiers.
[b]A concentration greater than the value shown was reported but is considered anomalous because of high turbidity or analytical qualifiers.

At the millsite, sodium plus potassium and calcium are the dominant cations and sulfate is the dominant anion. Calcium is the dominant cation and sulfate is the dominant anion in upper flow-system ground water downgradient of the millsite.

4.4.3.2 Burro Canyon Aquifer

In samples collected from the Burro Canyon aquifer, the only TCL VOCs detected at concentrations exceeding LRLs were methylene chloride and acetone, both of which are commonly observed as laboratory contaminants. No TCL semi-VOCs, pesticides/PCBs, or herbicides were reported above LRLs in samples collected from the Burro Canyon aquifer.

Maximum radiological and metals analyte activities/concentrations, excluding anomalous results, reported during the baseline characterization for wells completed in the Burro Canyon aquifer are presented in Tables 4.4-4 and 4.4-5, respectively. Anomalous results include qualified results and results that were not confirmed by prior or subsequent analyses. Unlike the upper flow system, baseline characterization results do not indicate that radiological and/or metals contamination exists in the Burro Canyon aquifer at and in the vicinity of the MMTS.

Table 4.4-4. Maximum Radiological Analyte Activities (in pCi/L), Excluding Anomalous Results, Detected in the Burro Canyon Aquifer During the Baseline Characterization

Analyte	Upgradient	Millsite	Downgradient
Gross Alpha	<7-<40*	<11-<30*	<12-<41*
Gross Beta	<6.5-<30*	<6.7-<30	<9.9-<51*
Pb-210	<2	<2	<2
Po-210	<0.14-<0.9	<0.15-<1.5	<0.15-<0.73
Ra-226	1.8	0.8	1.4
Ra-228	<1-<3	<1-<5	<1-<3*
Rn-222	180	200	330
Th-230	<0.07-<0.3*	0.76	0.42
Th-232	<0.05-<0.3	0.6	<0.04-<0.3
U	2.8	2.9	6.2*
U-234	12	1.1*	4*
U-235	0.35	<0.09-<0.24	<0.06-<0.21
U-238	3.2	0.86*	1.7*

*An activity/concentration greater than the value shown was reported but is considered anomalous and not confirmed by prior or subsequent analyses.

Table 4.4-5. Maximum Metals Concentrations (in μg/L), Excluding Anomalous Results, Detected in the Burro Canyon Aquifer During the Baseline Characterization

Analyte[a]	Upgradient	Millsite	Downgradient
Aluminum	304	54	57[b]
Arsenic	8.9	2.2	3.7[b]
Boron	150	97	70[b]
Iron	690	340[b]	1,500
Lead	12	2.1[b]	6.1
Manganese	770	420	330
Molybdenum	61	2.8	1.6[b]
Strontium	1,900	1,600	1,500[b]
Zinc	20	33	28

[a]Does not include analytes that either were not detected at concentrations above LRLs or detected at concentrations above LRLs, but the results are considered anomalous because of analytical qualifiers or were not confirmed by prior or subsequent analyses.
[b]A concentration greater than the value shown was reported but is considered anomalous because of analytical qualifiers or were not confirmed by prior or subsequent analyses.

On the basis of common ion data, calcium-bicarbonate is the most dominant cation-anion pair characterizing ground water in the Burro Canyon aquifer upgradient and downgradient of the millsite. The most dominant cation compositions in ground water beneath the millsite include calcium plus magnesium and sodium plus potassium. Bicarbonate is the most dominant anion in ground water at the millsite.

4.4.3.3 Surface Water

Radiological analytes and metals were the most commonly detected analytes in surface water samples collected during the baseline characterization. Some TCL VOCs were also detected during the baseline characterization including acetone, 1,2-DCA, methylene chloride, 4-methyl-2-pentanone, and toluene. Acetone, methylene chloride, and toluene are commonly observed as laboratory contaminants. No TCL semi-VOCs, pesticides/PCBs, or herbicides were detected at or above LRLs during the baseline characterization.

Maximum radiological analyte activities reported for surface water samples collected during the baseline characterization are presented in Table 4.4-6. Radiological analytes detected in surface water during the baseline characterization included gross alpha, gross beta, Pb-210, Ra-226, Rn-222, Th-230, U, U-234, U-235, and U-238. Ra-228 and Th-232 were not detected at or above LRLs in any of the surface water samples collected during the baseline characterization. Ra-226, Rn-222, Th-230, U, U-234, and U-238 were the radiological analytes detected at or above LRLs in samples collected from upgradient surface water sites.

Table 4.4-6. Maximum Radiological Analyte Activities (in pCi/L) Detected in Surface Water Samples Collected During the Baseline Characterization

Analyte	Upgradient	Millsite	Downgradient
Alpha	<9.9-<60	1,900	350
Beta	<6.7-<40	1,100	130
Pb-210	<2	9.3	2.7
Po-210	<0.13-<0.5	<0.16-<0.8	<0.15-<1.1
Ra-226	0.2	9.1	1.3
Ra-228	<1-<4	<3-<9	<1-<5
Rn-222	170	3,300	490
Th-230	0.23	0.81	0.58
Th-232	<0.05-<0.3	<0.3-<5.3	<0.06-<0.5
U	4.8[a]	2,900[a]	510[a]
U-234	4.8	1,100	180
U-235	<0.13-<0.26[b]	43	2.5
U-238	2.1	1,100	174

[a] Analytical result reported in μg/L.
[b] A concentration greater than the value shown was reported but is considered anomalous because of analytical qualifiers or was not confirmed by prior or subsequent analyses.

Maximum metals concentrations reported for surface water samples collected during the baseline characterization are presented in Table 4.4-7. Metals detected in surface water during the baseline characterization included aluminum, arsenic, boron, barium, iron, mercury, manganese, molybdenum, lead, selenium, strontium, vanadium, and zinc. Except for mercury, all of these metals were detected in at least one sample collected from millsite and downgradient sites. Mercury was only detected in surface water at the millsite. Silver, beryllium, cadmium, cyanide, cobalt, chromium, copper, nickel, antimony, and thallium were not detected at or above LRLs in any of the samples collected from upgradient, millsite, or downgradient surface water sampling sites.

On the basis of common ion results obtained during the baseline characterization, calcium plus magnesium-sulfate plus chloride is the dominant cation-anion pair characterizing surface water in Montezuma Creek in the vicinity of the MMTS.

Table 4.4-7. Maximum Metals Concentrations (in µg/L) Detected in Surface Water Samples Collected During the Baseline Characterization

Analyte*	Upgradient	Millsite	Downgradient
Aluminum	410	1,400	3,600
Arsenic	3.9	450	15
Boron	97	400	120
Barium	79	120	100
Iron	540	1,400	4,500
Manganese	120	790	460
Molybdenum	20	320	91
Lead	7.1	5.1	6.5
Selenium	9.7	41	20
Strontium	3,500	3,000	2,600
Vanadium	5.4	7,800	280
Zinc	22	38	87

*Does not include analytes that were not detected at or above LRLs in upgradient, millsite, and downgradient areas.

4.5 Task 4 Ecological Risk Assessment

An ecological risk assessment is being conducted for OU III to determine whether elevated concentrations of millsite-related contaminants are adversely affecting the Montezuma Creek ecosystem.

Preliminary activities, which were used to develop the current plan for the ecological risk assessment, are presented in Sections 4.5.1 and 4.5.2. Sections 4.5.3 through 4.5.5 present the proposed ecological risk assessment activities to be performed under the RI.

An eight-step approach, recommended by EPA Region VIII, is being used for this risk assessment. The eight steps are:

Step 1. Preliminary Problem Formulation and Ecological Effects Evaluation. Existing soil, surface water, ground water, and ecological data are used to generate preliminary lists of COPCs, receptors, and endpoints, and to produce a preliminary conceptual site model. This step has been completed and is presented in Section 4.5.1.3, Preliminary Problem Formulation.

Step 2. Preliminary Exposure Estimate and Risk Calculation. Existing abiotic media COPC concentration data are used to calculate preliminary exposure point concentrations,

chemical intakes by receptors, hazard quotients, and preliminary remedial goals. This step has been completed and is presented in Section 4.5.2, Preliminary Site Calculations.

Step 3. Problem Formulation: Assessment Endpoint Selection and Formulation of a Testable Hypothesis. COPC and assessment endpoints and are refined from preliminary site calculations and then finalized. Testable hypotheses are formulated to determine whether the assessment endpoints are being adversely affected. This step has been completed and is presented in Section 4.5.3, Problem Formulation.

Step 4. Problem Formulation: Conceptual Model Development, Measurement Endpoint Selection, and Study Design. Measurement endpoints and the conceptual site model are finalized. This step has been completed and is presented in Sections 4.5.3, Problem Formulation, and 4.5.4, Study Design.

Step 5. Site Assessment. The site will be visited to confirm the study design. Primarily, this visit is intended to ensure that sampling stations are located in appropriate areas. This step is addressed in Section 4.5.4, Study Design.

Step 6. Site Field Investigation. The study design that was formulated in Step 4 is implemented. The strategy for completing this step is presented in Section 4.5.4, Study Design. This step will be completed during the 1995 field season.

Step 7. Risk Characterization. The data collected in the Site Field Investigation are statistically analyzed and calculations are performed to quantify ecological risk. The strategy for completing this step is presented in Section 4.5.5, Risk Characterization.

Step 8. Risk Management. This is the final step of the ecological risk assessment. Information from the RI/FS will support risk management decision; however, risk management is not part of this Work Plan. Risk management decisions will be made by DOE, EPA, and the State of Utah.

This Work Plan presents the results of all preliminary ecological risk assessment activities and a plan for the completion of all remaining ecological risk assessment activities.

4.5.1 Preliminary Site Characterization

Preliminary site characterization involves reviewing existing sediment, hydrology, air, and ecological data, locating an appropriate reference area on the basis of existing site data, and conducting preliminary problem formulation activities.

4.5.1.1 Existing Site Information

Previous investigations, including sediment, hydrologic, ecological, and air studies, are described in Section 3.0 of this Work Plan. In addition, three data-collection activities were

conducted in the summer of 1994: a geomorphological study, a vegetation and soil survey, and a literature search for animal species that could inhabit OU III.

The geomorphological survey and vegetation and soil survey were conducted in support of an earlier, unpublished, Work Plan. The maps that were generated by these surveys will be finalized if it is determined that the nature and extent of contamination need to be identified.

Geomorphological Survey

The geomorphological survey consisted of identifying and mapping sediment depositional features throughout the study area. These activities included delineating the boundaries of geomorphic and hydrologic features that could be useful in defining sampling strata; mapping evidence of recent flooding, erosion, or deposition; and identifying channel forms, stream hydraulic regimes, and sediment transport mechanisms likely to affect the deposition and preservation of contaminated sediments. Findings of the geomorphological survey are summarized below.

A large part of Montezuma Creek downstream from the MMTS is confined by the steep sandstone walls of Montezuma Canyon. Deposits within the Montezuma Creek valley consist of colluvial fans draped from the canyon walls and fluvial sediments. The significant geomorphological features characteristic of this stretch of Montezuma Creek include the entrenched meanders of the creek, a narrow active floodplain, several sets of terraces, and numerous ponds and wetlands. The lower terrace adjacent to the stream is subject to overbank deposition of fine-grained sediments and appears to correlate with the highest surveyed Ra-226 activity. There is some evidence of high Ra-226 activity associated with the beaver ponds and depressions along the creek. Ponds and wetlands could act as natural sediment traps for contaminated tailings being transported down the creek. However, the coarse bed material in the active channel and the corresponding low gamma readings suggest that the fine-grained tailings have been flushed downstream or reside within overbank deposits of the lower terrace.

Vegetation and Soil Survey

A vegetation and soil survey was conducted to provide detailed maps that would enable risk assessors to identify where various animal receptors could occur. The survey was conducted in the summer of 1994.

Areas of dominant vegetation were identified during initial site reconnaissance. These dominant vegetation units were identified by looking down on the canyon bottom from the canyon rim, and walking along the canyon bottom. The units were mapped on 2-foot contour topographic maps.

A modified releve technique (Bonham 1989) was used to describe the major units. Parameters that were recorded in the releves were site condition, plant species present, cover class of dominant plant species, elevation, slope, and aspect. Approximately three releves were conducted in each major vegetation unit.

Standard soil survey techniques (U.S. Department of Agriculture Soil Conservation Service 1993) were used to describe the soils in each releve area. Information on the following parameters was collected: horizon designation, horizon depth and thickness, dry and moist color (using Munsell color charts), texture estimations, structure, and horizon boundaries characteristics. One soil pit was dug in each vegetation releve area.

Each major vegetation and soil unit is described below.

Sagebrush/Wheatgrass

Big sagebrush and fringed sagebrush (*Artemisia tridentata* and *A. frigida*) are the dominant shrubs in this unit, although skunkbush and rabbitbrush (*Chrysothamnus nauseosus*) also occur. Dominant grasses include western wheatgrass (*Agropyron smithii*), crested wheatgrass (*Agropyron cristatum*) and foxtail barley (*Hordeum jubatum*). A variety of forbs (yarrow [*Achillea* spp.], lupine [*Lupinus* spp.], milk vetch, yellow sweetclover, and globemallow [*Sphaeralcea* spp.]) and pricklypear were also found.

Soils within this unit occur on strongly sloping (5-12 percent) toeslopes and are moderately deep (50-100 cm) or deep (100-150 cm). Layering within the soils usually includes an organic-rich, loam surface horizon and one or more loam or clay loam subsurface horizons. The soils are well drained, and the water table is very deep (greater than 150 cm). Parent materials include loess and colluvium. Soils contain variable characteristics and may be classified as (1) fine-loamy, mixed, mesic Pachic Haplustolls; (2) fine-loamy, mixed, mesic Pachic Argiustolls; and (3) fine-loamy, mixed, mesic Typic Ustochrepts.

Rabbitbrush/Cheatgrass

Dominant species in this unit are rabbitbrush, sagebrush (*Artemisia* spp.), snakeweed (*Gutierrezia sarothrae*), cheatgrass (*Bromus tectorum*), crested wheatgrass, and western wheatgrass. Numerous forb species exist, including paintbrush (*Castilleja* spp.), aster (*Aster chilensis)*, penstemon (*Penstemon* spp.), iris (*Iris missouriensis*), yellow sweetclover, mallow (*Malva* spp.), lupine, and globemallow.

Soils within this unit occur on gently to strongly sloping (2-12 percent) floodplains, toeslopes, and benches. Much of this habitat type appears to have been disturbed at one time. Soils exhibit variable characteristics but are consistently deep (greater than 150 cm).

Soil layers include a loam, silt loam, or sandy loam surface horizon and several subsurface horizons of textures similar to the surface horizon. The surface horizon and sometimes one or more subsurface horizons are organically enriched. The soils generally are well drained, but some may have a seasonal water table below 60 cm. Parent materials include alluvium and sometimes colluvium derived from upper slopes. Soils generally are classified as fine-loamy, mixed, mesic Pachic Haplustolls; those lacking an organic-rich surface horizon may be classified as coarse-loamy, mixed, mesic Typic Ustorthents.

Willow/Grass

In this unit, willows (*Salix exigua, S. lasiandra,* and others) form dense thickets with grassy understories. Species in grassy patches include various wheatgrasses, redtop (*Agrostis stolonifera*), bullrush (*Scirpus* spp.), horsetail (*Hippochaete laevigata* and *Equisetum arvense*), mullein (*Verbascum thapsus*), mallow, Canada thistle (*Cirsium arvense*), and Russian knapweed (*Centaurea repens*).

Soils within this unit occur on nearly level (0-3 percent slopes) floodplains and alluvial bottoms. They are consistently deep (greater than 150 cm). Layering within the soils includes an organic-rich, loam or sandy loam surface horizon and several organic-rich subsurface horizons that vary in texture. Subsurface textures may include sand, loamy sand, sandy loam, loam, sandy clay loam, and/or clay loam. The soils are somewhat poorly drained and have a seasonal water table within 5-30 cm of the surface. Parent materials include recently and historically laid layers of alluvium. Soils generally are classified as fine-loamy, mixed, mesic Cumulic Haplaquolls. The family particle size class may vary, depending on the texture of the underlying alluvial layers.

Willow/Rush

Willow/rush units occur in moister areas adjacent to willow/grass units. These units support many of the same species as in the willow/grass units, but there is a higher proportion of sedges (*Carex* spp.), rushes (*Juncus* spp.), horsetails (*Hippochaete laevigata* and *Equisetum arvense*), field mint (*Mentha arvensis*), and other wetland plants.

Soils within this unit occur on nearly level (0-3 percent slopes) alluvial bottoms. These soils are very similar to soils within the Willow/Grass habitat type except they are poorly drained and have a permanent water table within 50 cm of the surface. Soils generally are classified as fine-loamy over sandy, mixed, mesic Cumulic Haplaquolls.

Grass (Lower Canyon)

Grassy areas in the lower section of Montezuma Creek are heavily grazed, making plant identification difficult. Plants identified were primarily weed species, including bindweed (*Convulvulus arvensis*), plantain (*Plantago lanceolatai),* dock (*Rumex crispus*), sweetclover (*Melilotus officianale* and *M. alba*), and cheatgrass.

Soils within this unit occur on nearly level to gently sloping (0-5 percent slopes) alluvial bottoms. They are consistently deep (greater than 150 cm). Layering within the soils includes a loam surface horizon, which may or may not be organically enriched, and very or extremely gravelly subsurface horizons. The soils are somewhat poorly drained and have a seasonal water table within 5-30 cm of the surface. A permanent water table is within 75 cm of the surface. Parent materials include recently and historically laid layers of alluvium. Of the two soil profiles observed in this habitat type, one is classified as a sandy-skeletal, mixed, mesic

Aquic Ustifluvent, and the other is classified as a loamy-skeletal, mixed, mesic Cumulic Haplaquoll.

Rushes (Lower Canyon)

The rush vegetation unit occurs in moist areas adjacent to grassy areas in the lower part of the canyon. Plants include redtop, foxtail barley, various rushes and sedges, field mint, and horsetails.

Soils within this habitat type occur on nearly level (0-3 percent slopes) alluvial bottoms. They are consistently quite deep. Layering within the soils includes a loam surface horizon and one or more very gravelly subsurface horizons. The soils are poorly drained and have a permanent water table within 50 cm of the surface. Parent materials include recently and historically laid layers of alluvium. Soils generally are classified as loamy-skeletal, mixed, mesic Typic Fluvaquents.

Species List

In the absence of extensive site-specific wildlife data, a list of wildlife species that could inhabit southeastern Utah was compiled from the literature. This list is presented in Table 4.5-1. The species list was used in conjunction with records of incidental wildlife sightings and the threatened and endangered species list in Section 3.3.4 as a basis for identifying potential receptors of concern.

4.5.1.2 Reference Location

Once on-site data were compiled, a reference location was identified. Various canyons in the Monticello area were evaluated to determine whether they were similar enough to Montezuma Creek in geology, hydrology, and ecology to be adequate for use as reference areas. Verdure Creek was selected as the reference location because of its similarity to Montezuma Creek. A major difference between Montezuma Creek and Verdure Creek, however, is the presence of the City of Monticello in the upper reaches of Montezuma Creek; Verdure Creek does not have a city in its upper reaches. This difference will be considered when site data are compared to background data in the ecological risk assessment. Vega Creek, just upstream of U.S. Highway 666, was selected as a secondary reference location for sampling media that are not available for collection at Verdure Creek. The locations of the reference areas are illustrated in Figure 4.5-1.

4.5.1.3 Preliminary Problem Formulation

Preliminary problem formulation involves using existing site data to establish preliminary lists of COPCs, receptors, and endpoints, and to formulate a preliminary conceptual site model. A preliminary list of COPCs is a compilation of uranium mill tailings-related contaminants that have been detected by previous soil, sediment, and hydrologic investigations, and priority pollutant metals for which little or no data exist. This preliminary list was presented to the

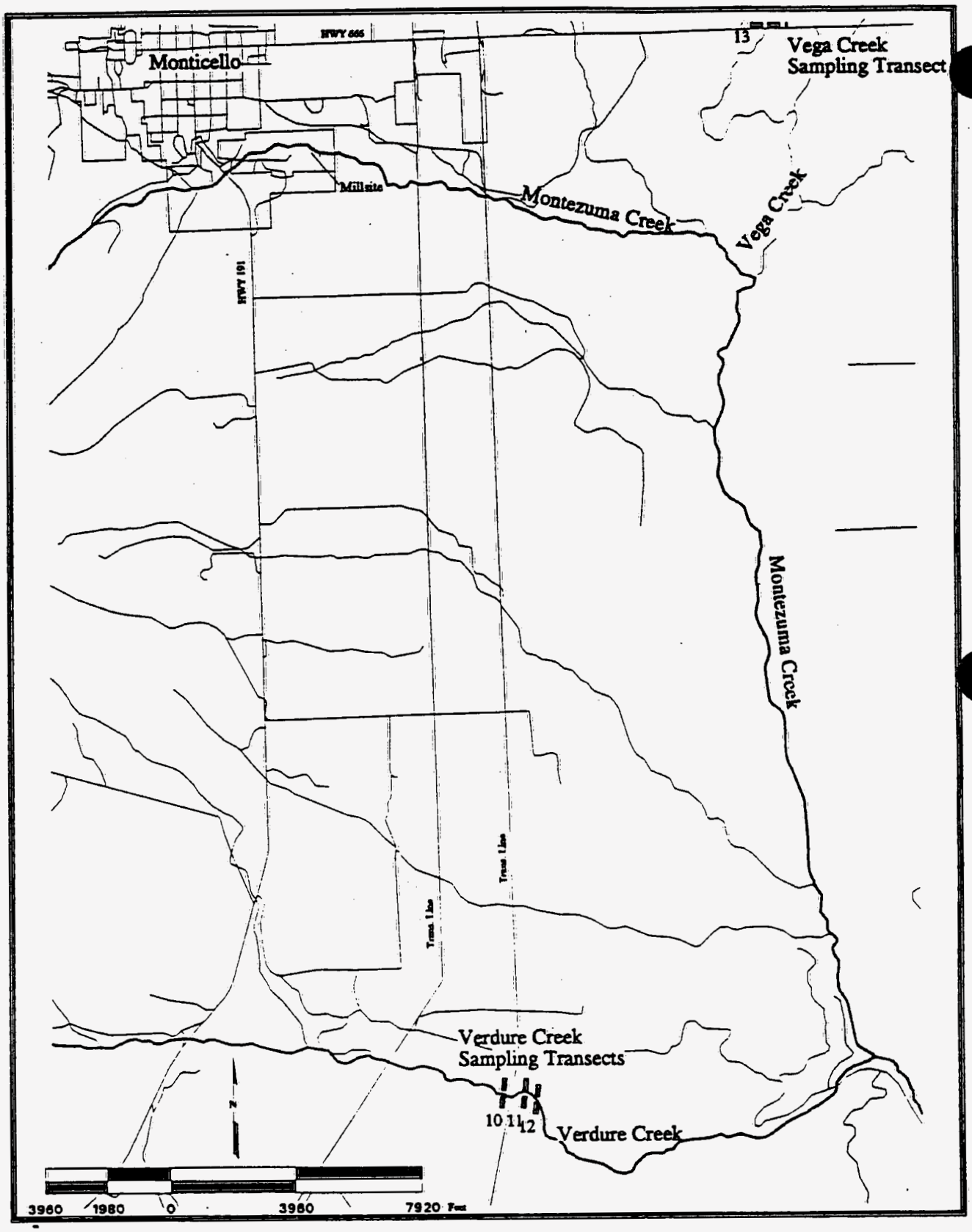


Figure 4.5-1. Proposed Sample Transect Locations for the OU III RI/FS Reference Areas

ETAG in the concept paper, *Technical Approach for the Operable Unit III Risk Assessments and Groundwater Modeling* (DOE 1994d), and ETAG concurrence was received. Table 4.5-2 lists the preliminary COPCs for abiotic and biotic media.

Potential receptors were selected from general species lists for southeastern Utah (see Table 4.5-1) and threatened and endangered species lists (see Section 3.3.4). The following criteria were used to select the indicator species:

- High likelihood of exposure.
- High social or ecological significance.
- Availability of toxicological literature for the species or surrogate.
- Possibility of population-level adverse effects from OU III stressors.

A preliminary list of receptors developed during the October 5, 1994, ETAG meeting includes mule deer, beaver or muskrat, golden eagle, peregrine falcon, southwestern willow flycatcher, spotted bat, fish in Montezuma Creek, and endangered fish, including razorback sucker [*Xyrauchen texanus*], bonytail chub [*Gila elegans*], humpback chub [*Gila cypha*], Colorado squawfish [*Ptychocheilus lucius*] in the San Juan River (see Figure 4.5-2).

A preliminary conceptual site model was developed on the basis of expected migration pathways of COPCs and the preliminary list of receptors. Figure 4.5-3 illustrates this model.

Assessment and measurement endpoints were selected to reflect the preliminary receptors of concern. These preliminary endpoints are listed in Table 4.5-3.

The COPC list, receptor list, conceptual site model, and assessment and measurement endpoints are refined in Section 4.5.3, Problem Formulation.

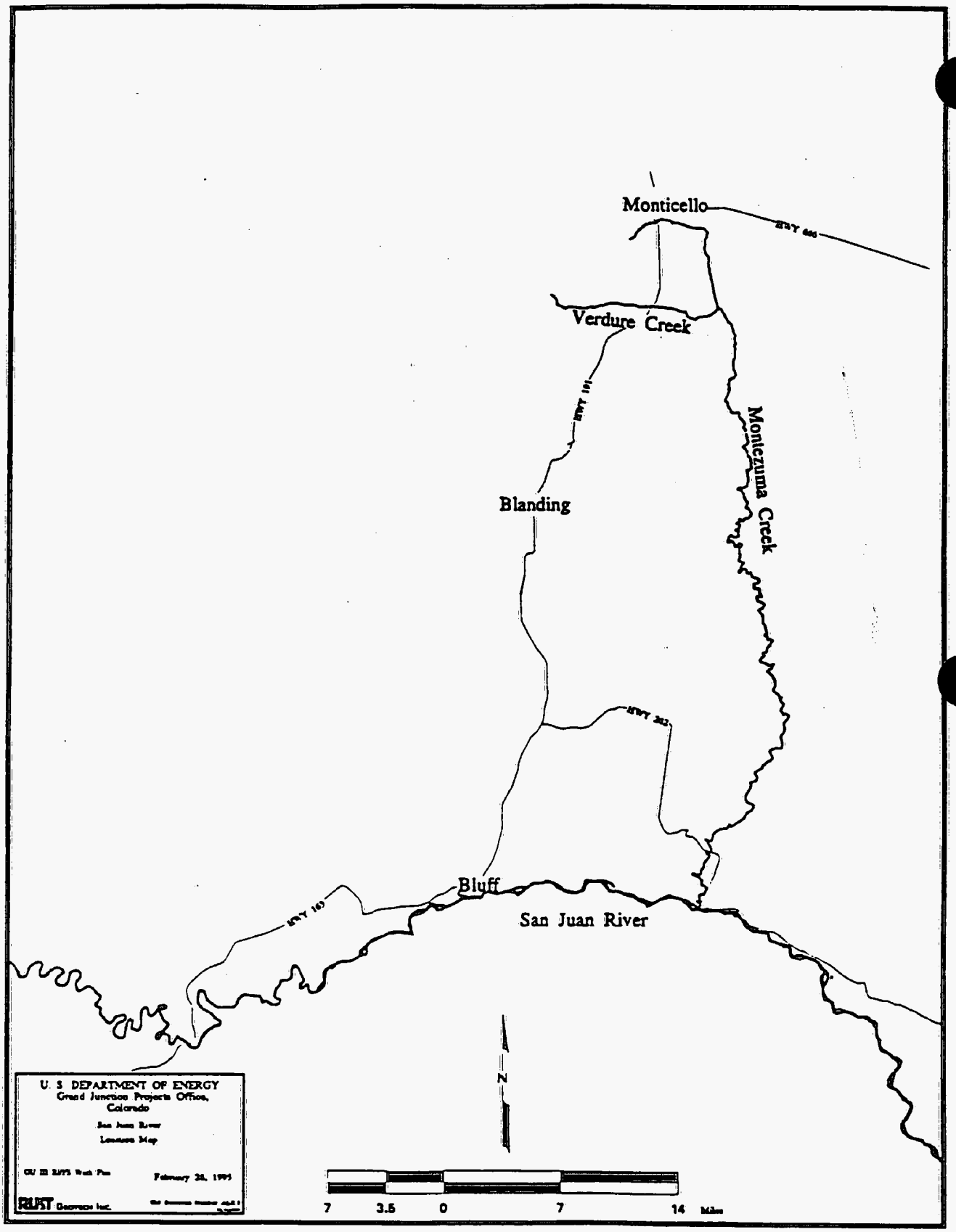


Figure 4.5-2. San Juan River Location Map

Table 4.5-2. Preliminary COPCs in Abiotic and Biotic Media at OU III

Target Analyte	Soil	Sediment	Surface Water	Biota
Heavy Metals				
Aluminum	X	X	X	
Antimony	X	X		
Arsenic	X	X	X	X
Barium	X	X	X	
Beryllium	X	X		
Cadmium	X	X	X	X
Chromium	X	X	X	
Cobalt	X	X		
Copper	X	X	X	X
Iron	X	X	X	
Lead	X	X	X	X
Manganese	X	X	X	
Mercury	X	X	X	X
Molybdenum	X	X	X	
Nickel	X	X	X	
Nitrate			X	
Selenium	X	X	X	X
Silver	X	X	X	
Sulfate			X	
Thallium	X	X	X	X
Tin	X	X	X	
Uranium	X	X	X	X
Vanadium	X	X	X	
Zinc	X	X	X	X
Radionuclides				
Lead-210	X	X	X	X
Potassium-40	X	X		
Uranium-234	X	X	X	X
Uranium-238	X	X	X	X

Table 4.5-2. Preliminary COPCs in Abiotic and Biotic Media at OU III (Continued)

Target Analyte	Soil	Sediment	Surface Water	Biota
Radium-226	X	X	X	X
Thorium-230	X	X	X	X
Thorium-232	X	X		

Table 4.5-3. Preliminary Assessment and Measurement Endpoints for OU III.

Assessment Endpoint	Measurement Endpoints
Protection of mule deer populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of preliminary COPCs in willows. • Measure concentrations of preliminary COPCs in perennial grasses. • Measure concentrations of preliminary COPCs in bovine or deer liver, kidney, and muscle. • Conduct population surveys to document foraging behavior, population status of mule deer. • Measure concentrations of preliminary COPCs in surface water and soils.
Protection of southwestern willow flycatcher and spotted bat populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of preliminary COPCs in cliff swallow nestlings (liver, kidney) as a surrogate for southwestern willow flycatcher and spotted bat. • Conduct histopathology analysis on cliff swallow nestling (liver, kidney) to determine pathological changes. • Conduct population surveys to document avian species occurrence, diversity, density, and other indications of population status. • Measure concentrations of preliminary COPCs in surface water.
Protection of peregrine falcon populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of preliminary COPCs in cliff swallow nestlings (whole body) to represent dietary intake of peregrine falcons. • Conduct population surveys to document foraging, nesting activity of peregrine falcons. • Measure concentrations of preliminary COPCs in surface water and soils.
Protection of golden eagle populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of preliminary COPCs in ground squirrels to represent dietary intake of golden eagle. • Conduct population surveys to document foraging, nesting activity of golden eagles. • Measure concentrations of preliminary COPCs in surface water and soils.
Protection of beaver or muskrat populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of preliminary COPCs in beaver or muskrat liver and kidney. • Conduct histopathology analysis on beaver or muskrat liver and kidney to determine pathological changes. • Conduct population surveys to document riparian mammal foraging behavior, population status, species occurrence, diversity, and density. • Measure concentrations of preliminary COPCs in surface water and sediment.
Protection of prey species populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Conduct population surveys for earthworms, benthic invertebrates, and small mammals. • Measure concentrations of preliminary COPCs in surface water, sediment, and soils.

Table 4.5-3. Preliminary Assessment and Measurement Endpoints for OU III (Continued).

Assessment Endpoint	Measurement Endpoints
Protection of Montezuma Creek small, non-game fish populations and San Juan River endangered fish populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Compare water and sediment concentrations from Montezuma Creek and the San Juan River to benchmark ecotoxicity data to determine whether concentrations are harmful to fish. • Conduct population surveys for fish in Montezuma Creek if water or sediment concentrations exceed benchmark ecotoxicity concentrations.

4.5.2 Preliminary Site Calculations

The preliminary site calculations section includes a toxicity assessment, exposure assessment, and risk characterization. The toxicity assessment contains suggested toxicity benchmark values and water-quality criteria. The exposure assessment predicts estimated chemical intakes on the basis of media ingestion rates by receptors in Montezuma Canyon. The risk characterization compares the results of the previous two sections, draws conclusions, and makes recommendations that are based on the available data.

4.5.2.1 Preliminary Toxicity Assessment

Preliminary COPCs for OU III are presented in Table 4.5-2. The scientific literature was searched for screening criteria or toxicity benchmark values for these COPCs. These values represent concentrations at the site that, if exceeded, would indicate a possible risk to ecological receptors.

Data sources that were evaluated for toxicity information include:

- TOXLINE (an online database specializing in toxicological data).
- AQUIRE (EPA's online database for toxicological data on aquatic receptors).
- EPA documents.

These sources were searched for chronic toxicity studies specific to the contaminants and receptors at OU III. Long-term (chronic) studies were preferred over short-term (acute) studies because exposure at OU III is likely to be chronic for many of the ecological receptors. Health effects considered relevant were those likely to adversely affect population success, such as decreased reproductive success, decreased survivability, and morbidity.

When possible, data for OU III receptors (see Section 4.5.1.3) and the ingestion exposure pathway were used. When receptor-specific data were not available, data for wildlife or laboratory animals within the same class as the receptors, or data from other exposure pathways, were used.

Ideally, no observed adverse effect level (NOAEL) concentrations and lowest observed adverse effect level (LOAEL) concentrations from the literature were identified for each contaminant and each receptor. The lowest LOAEL and the highest NOAEL from the literature were used in preliminary calculations. When the LOAEL was lower than the NOAEL, the LOAEL was used. When the chronic NOAEL was greater than the subchronic NOAEL, the chronic NOAEL was used. When NOAEL and LOAEL concentrations were not available, LDLo (lowest lethal dose) concentrations, TDLo (lowest toxic dose) concentrations, LC_{50} (concentration at which 50 percent of exposed organisms die) values, and LD_{50} (dose at which 50 percent of exposed organisms die) values were considered; these data are not as certain as NOAEL and LOAEL concentrations.

When LOAEL concentrations were presented in chronic, non-lethal studies, the LOAEL concentrations were used without uncertainty factors. However, if chronic, non-lethal studies were not found, the following conservative uncertainty factors were applied:

- Each LD_{50} value was divided by 100.
- Lethal-endpoint LOAEL values for birds and mammals were divided by 10.
- Values with lethal- or reproductive-endpoint LOAEL values for plants and soil fauna were divided by 10.
- No uncertainty factors were applied to LC_{50}, LD_{50}, or TDLo values.

Many values were reported as dietary concentrations (i.e., milligrams per kilogram [mg/kg] diet or ppm). Dietary concentrations were converted to intakes (mg/kg body weight/day) using dietary ingestion rates.

Toxicological literature data are presented in Tables 4.5-4 and 4.5-5. Toxicity benchmark values (TBVs) for animals are in Table 4.5-4; TBVs for plants and soil fauna are in Table 4.5-5. Values in boldface were used to calculate hazard quotients (see Section 4.5.2.3).

Preliminary Ecotoxicity Profiles

A number of the metals present in Montezuma Canyon are essential in small amounts for animal nutrition. These include, but are not limited to, chromium, copper, iron, manganese, and zinc. Animals have developed a variety of homeostatic mechanisms for metabolism of essential metals, so these metals are less likely to produce toxic effects than are the nonessential elements such as barium, cadmium, and lead. Nevertheless, physiological control mechanisms can be overwhelmed or circumvented and some essential elements can produce toxic effects when an organism's exposure to concentrations greater than the optimum levels occurs.

The toxicity of many elements is influenced by the chemical speciation in which they occur. Concentrations in food stuffs and water are often the most important, although soil ingestion

may be a significant route of exposure for some animals. Because potentially toxic trace elements occur in different chemical forms of varying toxicity, total concentration of some elements in the exposure media may not be a good predictor of potential adverse effects. This section attempts to identify both highly toxic and environmentally predominant forms in abiotic media in order to provide insight into potential health risks.

Toxicity data were not available for all of the COPCs listed in Table 4.5-2. Ecotoxicity profiles for most of the COPCs are provided below.

Aluminum is not known to be an essential element in animal nutrition. Intestinal absorption is generally very poor, and toxicity is low in comparison to that of many other metals.

Antimony has been reported to produce toxicity in several species of aquatic life, but studies on terrestrial wildlife and birds are lacking.

Arsenic can have multiple valance states. In general, inorganic arsenic compounds are more toxic than organic compounds. Organic arsenicals are used as feed additives in agriculture, and their biological fate and toxicity differ from those of the inorganic forms. Trivalent inorganic arsenicals (arsenites) are often more toxic than pentavalent compounds (arsenates). Arsenic is a teratogen and carcinogen that may cause death or malformations in mammals. Arsenic does not tend to bioaccumulate or biomagnify because it is readily metabolized and excreted. The arsenate form is likely to predominate in Montezuma Creek.

Barium is stimulatory but not essential to animals. It is considered relatively nontoxic at physiological concentrations, but toxic at higher levels. Homeostatic mechanisms maintain normal levels of barium to some extent.

Cadmium is highly toxic to most species at relatively low levels and it is bioaccumulative. Cadmium is not controlled by homeostasis; it is retained in tissues, and body burdens may increase with age and exposure duration. Freshwater biota tend to be sensitive to cadmium.

Chromium is an essential trace metal for mammals. Chromium is toxic at high doses, and certain chemical species are highly toxic. Hexavalent chromium is the most toxic form, although little information is available on the toxicological properties of organic chromium compounds, water-soluble chemical species, or interactions of different chromium compounds in complex mixtures. Hexavalent chromium is chemically reduced in the acid fluid of the mammalian stomach. Chromium concentrations are usually highest at the lowest trophic levels, which may be in more direct contact with the abiotic source media. Biomagnification has not been observed in food chains. Hexavalent chromium is unlikely to be present at Montezuma Creek.

Copper is an essential trace metal that stimulates growth when moderately high levels are fed to mammals, but it is highly toxic to aquatic organisms. Ruminants (e.g., cattle) tend to be more sensitive to copper toxicity than monogastric animals.

Iron is an essential metal. It is generally not considered to be toxic; however, high doses may be toxic to mammals. Little information is available regarding toxicity of iron to aquatic organisms. Iron may be toxic to freshwater aquatic species under mildly acidic conditions.

Lead is a nonessential metal. Lead compounds are readily absorbed from the digestive tract. Organic lead compounds are more toxic than inorganic salts because they are more readily bioavailable. Organic lead compounds have greater lipid solubility, higher stability in biological fluids, and greater assimilation into target tissues such as the central nervous system and the brain. However, inorganic species are the primary forms of lead in the environment. Inorganic lead may be toxic to aquatic and terrestrial biota. Inorganic lead is the most likely form of lead to be related to millsite activities.

Manganese salts appear to be among the least toxic of the essential metals. An efficient homeostatic mechanism prevents manganese from accumulating in tissues. Toxic or adverse effects due to exposure to manganese are not common.

Mercury is a nonessential element for animals. It occurs in inorganic and organic forms; organic mercury is more bioavailable and more toxic than inorganic mercury. Inorganic mercury is methylated in biotic and abiotic media. Mercury is bioaccumulative.

Selenium also is an essential trace element that is toxic at greater than optimum doses. Selenium is bioconcentrated to some extent by both aquatic and terrestrial species. Plants can concentrate selenium to levels that are toxic to mammals. Selenium is toxic to aquatic and terrestrial life and has been indicated as a teratogen in waterfowl.

Uranium, aside from its radiological properties, is primarily toxic to the kidney. It also concentrates in bone tissue. Parkhurst et al. conducted laboratory tests in which brook trout *(Salvelinus fontinalis)* and fathead minnows *(Pimephales promelas)* were exposed to uranium (Parkhurst et al. 1984). Concentrations estimated to be chronically toxic exceeded 9 milligrams per liter (mg/l) (Parkhurst et al. 1984). Hardness and alkalinity inversely influenced uranium toxicity in this study. In a lake contaminated by uranium mine tailings, no adverse effects on blood hematocrit, rates of parasitism, and histopathology were detected in whitefish *(Coregonus clupeaformis)* (Waite et al. 1990).

Zinc is an essential trace metal that is relatively nontoxic because of efficient homeostatic mechanisms that maintain a proper balance within the body. High concentrations in water may adversely affect aquatic life.

Surface Water Criteria

Surface water criteria for aquatic receptors include the federal Ambient Water Quality Criteria (AWQC) and Utah State Standards presented in Table 4.5-6. The value for uranium is the chronic value reported by Parkhurst (Parkhurst et al. (1984). Surface water criteria for terrestrial receptors are presented in Table 4.5-6 as well. The media specific ingestion rates used to derive these surface water criteria are described in Section 4.5.2.2. These criteria are

Table 4.5-6. Summary of Preliminary Surface Water Criteria for Aquatic and Terrestrial Receptors

	Federal and State Criteria ug/L				Criteria Calculated from Toxicity Benchmark Values (Table 4.5-4) mg/L					
	Federal AWQC		Utah State (3A)							
Analyte	Acute	Chronic	Acute	Chronic	Passerine	Raptor	Small Herbivore	Large Herbivore	Small Omnivore	Large Omnivore
Ag	4.1	0.12	4.1	0.12	NA	NA	325.00	1040.00	520.00	1040.00
Al	750	87	750	87	NA	NA	NA	NA	NA	NA
As	360	190	360	190	56.00	56.00	19.00	40.00	30.40	76.00
Ba	NA	NA	NA	NA	4000.00	4000.00	25.50	102.00	40.80	102.00
Be	130	5.3	NA	NA	NA	NA	2.70	10.80	4.32	10.80
Cd	3.9 •	1.1 •	3.9 •	1.1 •	0.80	0.80	12.50	0.04	20.00	50.00
Co	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr	1700 •	210 •	1700 •	210 •	NA	NA	NA	NA	NA	NA
Cu	18 •	12 •	18 •	12 •	116.00	116.00	75.00	8.00	120.00	300.00
Fe	NA	1000	1000	1000	NA	NA	500.00	2000.00	800.00	2000.00
Hg	2.4	0.012	2.4	0.012	0.07	0.07	0.90	3.60	1.44	15.00
Mn	NA	NA	NA	NA	NA	NA	700.00	1600.00	1120.00	2800.00
Mo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Na	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ni	1400 •	160 •	1400 •	160 •	NA	NA	120.75	483.00	193.20	483.00
NO3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb	82 •	3.2 •	82 •	3.2 •	58.00	58.00	1.50	24.00	2.40	6.00
SO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb	88	30	NA	NA	NA	NA	NA	NA	NA	NA
Se	20	5	20	5	0.35	0.35	0.29	1.60	0.46	1.14
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	1400	40	NA	NA	0.95	0.95	NA	NA	NA	NA
U	NA	9000 a	NA	NA	344.00	344.00	14.00	56.00	22.40	56.00
V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn	120 •	110 •	120 •	110 •	6.80	6.80	375.00	800.00	600.00	1500.00
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	4.8	4.8	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: Utah criteria for metals are for dissolved fraction, not to be exceeded more than once every 3 years, average. Acute = 1 hr 'average; Chronic = 4 day average. Inorganics = ug/L; radionuclides = pCi/L.

• - indicates hardness dependent criteria; hardness of 100 mg/L used to calculate criteria.

NA - Criteria not available in the literature reviewed.

a - Chronic value reported by Parkhurst et al. (1984)

calculated from TBVs in Table 4.5-4, and are those concentrations in surface water that correspond to TBV, assuming 100 percent of chemical intake from the surface water medium.

Sediment Criteria

Sediment criteria were compiled by Bennett and Cubbage and are reported in Table 4.5-7. Values for uranium were unavailable (Bennett and Cubbage 1991). Therefore, the values observed by Waite, where no adverse effects were documented in whitefish, are recommended at this time (Waite et al. 1990). This concentration may be overly conservative, as concentrations correlating with adverse health effects were unavailable.

4.5.2.2 Preliminary Exposure Assessment

The Exposure Assessment presents the complete exposure pathways, media ingestion rates, summaries of available abiotic data, and estimates chemical-specific intakes.

Complete Exposure Pathways

Exposure pathways for each of the receptors of concern are outlined in Figure 4.5-3, the preliminary conceptual site model. An exposure pathway is considered complete if it contains a source and/or exposure medium, a mechanism of release, an exposure route, and a receptor. It is unlikely that all of the exposure pathways in the conceptual site model are complete. For the purposes of the preliminary site calculations, only those pathways that are expected to be primary sources of exposure to the receptors are evaluated.

In some instances, exposure pathways that may be complete could not be quantified for some chemicals because toxicity information was unavailable. In other cases, the pathway was qualitatively evaluated and was found to be an unlikely source of significant exposure, and was not quantified.

Table 4.5-7. Preliminary Summary of Sediment Criteria for Metals

Analyte	Range (mg/kg, dry weight)*
Arsenic	<3 - 33
Barium	<20 - 500
Cadmium	0.6 - 10
Chromium	<25 - 120
Copper	16 - 110
Iron (%)	1 - 5.9
Lead	31 - 500
Manganese	<300 - 1200

Table 4.5-7. Preliminary Summary of Sediment Criteria for Metals (Continued)

Mercury	0.1 - 0.6
Nickel	16 - 100
Selenium	1 - 2
Silver	0.5
Uranium	27**
Zinc	<90 - 820

* Concentration ranges summarized from Bennett and Cubbage (Bennett and Cubbage 1991)
** Concentration at which no adverse effects were documented in whitefish (Waite et. al. 1990).

Inhalation, ground-water ingestion, and direct contact with water, sediment, and soil were not evaluated in these preliminary calculations. Exposure from these pathways probably is minimal for the following reasons: 1) air monitoring data indicate only low levels of radionuclides are present (air data are discussed more thoroughly in Section 3.4), 2) few seeps of sufficient flow to provide drinking water to wildlife have been identified in the canyon, so ground water ingestion is expected to be an insignificant exposure pathway, and 3) the metals and radionuclides at the site are not easily absorbed through the skin.

Indirect exposure routes, such as ingestion of prey, are likely to provide less exposure for nonbioaccumulative chemicals than the direct exposure routes. Because most of the preliminary COPCs at the site are metals that are not expected to be highly bioaccumulative, this pathway would provide less exposure than ingestion of source media. Therefore, these indirect routes were not evaluated in these preliminary calculations.

Media Ingestion Rates

Water-ingestion rates for various animals were used to calculate acceptable contaminant concentrations in surface water. The suggested surface-water criteria (Table 4.5-6) for terrestrial receptors were obtained by using the following water ingestion rate values (Sax 1984):

Ecological Receptor	Ingestion Rate (l/kg bw/day)	Test Species
Passerine	0.25	Chicken
Raptor	0.25	Chicken
Small herbivore	0.20	Mouse
Large herbivore	0.05	Cow
Small omnivore/carnivore	0.125	Rat
Large omnivore/carnivore	0.050	Dog, Cat

Other values documented by EPA *Wildlife Exposure Facorts Handbook* (EPA 1993e) indicate lower ingestion rates for avian species, but similar ingestion rates for small herbivores (Table 4.5-8). Actual ingestion rates for water are expected to vary by species, as well as by season, because of varying water contents of diet and differences in water demand.

Table 4.5-8. Preliminary Water Ingestion Rates for the Terrestrial Ecological Receptors

Ecological Receptor Catagory	Common Name[a]	Water Ingestion Rate [b] (L/kg bw/day) Mean (range)
Birds - general	Northern bobwhite	0.077 (0.034 - 0.131)
Raptors	NA	Assume 0.1
Mammals - Small herbivores	Meadow vole	0.21
	Deer mouse	0.19 (0.126 - 0.34)
	Prairie vole	0.242 (0.132 - 0.43)
		0.22[c]
Large herbivores	NA	Assume 0.1
Carnivores/Omnivores	Mink	0.080 (0.028 - 0.133)

NA - Not available
[a] Species for which water ingestion data were not available.
[b] EPA 1993c
[c] Arithmetic mean of mean water ingestion rates for meadow vole, deer mouse, and prairie vole.

Soil ingestion rates are presented in Table 4.5-9. Soil ingestion is typically expressed as a fraction of dietary intake. For wetland/riparian animals such as beaver, sediment is assumed to provide the bulk of the daily soil ingestion. Upland animals such as ground squirrels are assumed to contact soils, but not sediments.

Daily soil ingestion was based on information obtained in Beyer (Beyer et al. 1994), where percent soil in diet was multiplied by total daily dietary intakes to obtain a daily soil ingestion rate as follows:

Dietary Ingestion Rate	x	Percent Soil in Diet	=	Soil Ingestion Rate
(kg diet/kgbw)		(fraction)		(kg soil/kgbw)

Dietary and soil ingestion rates are unavailable for all of the ecological receptors identified at the site. Therefore, average dietary ingestion rates and average percent soil in diet were determined for each category of ecological receptor on the basis of data available for similar species. Table 4.5-9 presents the ecological receptor category to which the soil ingestion rate is applied,

Table 4.5-9. Preliminary Soil and Dietary Ingestion Rates for Birds and Mammals

Ecological Receptor	Representative (Test) Species	Dietary Ingestion Rate [1] (kg diet/kg bw/day) Mean (range)	Percent Soil in Diet [2]	Soil Ingestion Rate (kg soil/kg bw/day)
Birds - general	Woodcock	NA	9.1	
	Northern Bobwhite	0.089 (0.067 - 0.1)	NA	
	American Robin	0.63 (0.75 - 1.52)	NA	
	Turkey	NA	6.2	
	Arithmetic Mean	**0.36**	**7.65**	**0.028**
Raptors	American Kestrel	0.21 (0.11 - 0.31)	NA	
	Red-tailed Hawk	0.089 (0.055 - 0.112)	NA	
	Arithmetic Mean	**0.17**	**Assume 2.8**	**0.0048**
Small herbivores	Meadow Vole	0.325 (0.3 - 0.35)	2.4	0.0078
	Deer Mouse	0.21 (0.07 - 0.38)	NA	
	Prairie Vole	0.125 (0.09 - 0.14)	NA	
	Prairie Dog	NA	2.7	
	Muskrat	0.32 (0.31 - 0.33)	NA	
	White-footed Mouse	NA	< 2	
	Arithmetic Mean	**0.24**	**2.4**	**0.0048**
Large herbivores	Mule deer	0.053	< 2	0.0011
	Arithmetic Mean	**0.053**	**< 2**	**0.0011**
Small Carnivores/Omnivores	Shrew	0.59 (0.49 - 0.76)	NA	
	Fox Squirrel	0.059	NA	
	Arithmetic Mean	**0.32**	**Assume 2.4**	**0.0077**

NA - not available
[1] EPA, 1993c
[2] Beyer et al., 1991

and the common name of the species for which data were available. The dietary ingestion rate, percent soil in diet, and a calculated soil ingestion rate also are presented.

Where both a percent soil in diet and a dietary ingestion rate were obtained, a receptor specific soil ingestion rate was calculated. However, because most of the data available are for animals that are not target receptors for OU III (e.g., American robin), average values were determined for percent soil in diet and dietary ingestion rate for each catagory of receptor (e.g., passerine birds, raptors, small herbivorous mammals, etc.), and these average values were used in the calculations for site-specific receptors. These average values are presented in Table 4.5-9. Average values were not calculated for large herbivores because only one percent-soil-in-diet value was available. Average values also were not calculated for carnivores/omnivores because one value was for an upland animal and the other for a wetland species and it is likely that wetland species may ingest more soil/sediment than upland species.

Abiotic Media Data

The preliminary list of COPCs that are used in the Preliminary Site Calculations is presented in Table 4.5-2. Concentrations of COPCs in each abiotic medium were taken from previous investigations conducted for OU III. Surface water concentrations represent the mean and 95 percent upper confidence limit (95% UCL) contaminant concentrations in surface water samples collected between November 1, 1992, and May 10, 1994. Soil and sediment concentrations represent mean and 95% UCL contaminant concentrations in soil and sediment samples collected in October 1994.

The concentrations observed in surface water upgradient of the millsite, at the millsite, and downstream of the millsite are presented in Table 4.5-10. Soil data are presented in Table 4.5-11.

Daily Intakes

Daily intakes (milligram chemical/kilogram body weight/day [mg/kg bw/day]) for the ecological receptors were calculated for ingestion of surface water and soil. These values were obtained by multiplying the soil ingestion rates (Table 4.5-9) by the exposure point concentrations in sediment and soils, or by multiplying the water ingestion rates (Table 4.5-8) by the exposure point concentration in surface water.

Chemical intake for ingestion of contaminated surface water was estimated as follows:

Exposure Point Concentration	x	Daily Intake Rate	=	Chemical Intake
(μg/l)		(l/kg bw)		(μg/kg bw/day)

Table 4.5-10. Preliminary Surface Water Summary Data for Inorganics (µg/L) and Radionuclides (pCi/L)

	Up Gradient		On Site		Down Gradient		Federal AWQC		Utah State (3A)	
Analyte	Mean	Max	Mean	Max	Mean	Max	Acute	Chronic	Acute	Chronic
Ag*	ND	ND	ND	ND	ND	ND	4.1	0.12	4.1	0.12
Al	433.00	1450.00	443.00	1360.00	1007.00	3550.00	NA	NA	750	87
As	4.40	11.00	139.60	1250.00	2.80	15.10	360	190	360	190
Ba	83.90	141.00	56.10	117.00	64.40	103.00	NA	NA	NA	NA
Be	ND	ND	ND	ND	ND	ND	130	5.3	NA	NA
Ca	165292.40	431000.00	202310.00	358000.00	146986.00	324000.00	NA	NA	NA	NA
Cd*	ND	ND	ND	ND	ND	ND	3.9	1.1	3.9	1.1
Co	6.60	6.60	ND	ND	ND	ND	NA	NA	NA	NA
Cr*	4.90	4.90	ND	ND	5.10	26.30	1700	210	1700	210
Cu*	10.10	10.10	6.40	65.10	2.50	10.70	18	12	18	12
Fe	716.00	1670.00	480.60	1400.00	1004.80	4450.00	NA	1000	1000	1000
Hg	ND	ND	0.20	0.20	ND	ND	2.4	0.012	2.4	0.012
Mn	266.00	1000.00	167.60	785.00	183.90	460.00	NA	NA	NA	NA
Mo	10.00	20.20	175.00	2450.00	13.90	90.90	NA	NA	NA	NA
Ni*	5.00	13.30	5.20	11.40	6.40	11.60	1400	160	1400	160
NO3	NA	NA	NA	NA	NA	NA	15	15	15	15
Pb*	1.90	24.50	1.20	5.10	2.10	6.50	83	3.2	82	3.2
SO4	223611.90	100000.00	600493.00	138000.00	385105.60	787000.00	NA	NA	NA	NA
Sb	0.80	2.00	0.80	2.20	0.70	1.90	88	30	NA	NA
Se	2.20	9.70	38.00	540.00	2.30	19.60	20	5	20	5
Sn	NA	NA	NA	NA	NA	NA	15	15	15	15
Tl	ND	ND	ND	ND	ND	ND	1400	40	NA	NA
U	19.80	103.00	652.10	3230.00	93.60	508.00	9000	9000	NA	NA
V	9.30	29.80	3856.30	52000.00	20.80	280.00	NA	NA	NA	NA
Zn*	11.70	34.00	12.30	38.30	24.60	86.70	120	110	120	110
K40	NA	NA	NA	NA	NA	NA	15	15	15	15
Ra-226	0.60	2.40	2.40	9.1	0.30	1.3	NA	NA	NA	NA
Ra-228	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA
Th-230	0.07	0.20	0.54	0.81	0.12	0.58	NA	NA	NA	NA
Th-232	0.06	0.09	ND	ND	NA	NA	NA	NA	NA	NA
U-234	8.30	39.30	228.30	1064.7	33.90	176.5	NA	NA	NA	NA
U-238	6.90	38.10	228.40	1063.5	33.50	174.2	NA	NA	NA	NA
NO3	NA	NA	NA	NA	NA	NA	15	15	15	15

*Note: Utah criteria for metals are for dissolved fraction, not to be exceeded more than once every 3 years, average. Acute = 1 hr average; Chronic = 4 day average. Inorganics = µg/L; radionuclides = pCi/L. * indicates hardness dependent criteria; hardness of 100 mg/L*

Table 4.5-11. Concentrations of Analytes in Soil Samples Collected During 1994 Confirmatory Soil Sampling

	mg/kg	
	Avg.	UCL95
Ag	0.12	0.3
Al	8503.12	11511.67
As	7.36	13.62
Ba	169.06	245.7
Be	0.52	0.69
Cd	0.2	0.59
Co	5.87	8.49
Cr	6.95	9.62
Cu	57.95	166.61
Fe	11331.25	14898.16
Hg	0.02	0.03
K40	15.46	25.37
Mn	383.12	472.57
Mo	1.55	2.81
Ni	10.81	13.11
Pb	13.03	19.84
Ra226	17.91	61.36
Sb	2.8	6.22
Se	0.59	1.63
Sn	1.95	2.81
Th232	1.77	4.38
Tl	0.16	0.45
U	17.77	41.26
V	105.69	341.19
Zn	50.5	68.49

Summarized from analytical data for soil samples collected October 1994

Table 4.5-13. Preliminary Intakes (mg/kg bw/day) of Contaminants from Surface Soil Ingestion

Intake Based on Soil Concentration

	Passerine		Raptor		Small Herbivore		Large Herbivore		Small Omnivore/Carnivore		Large Omnivore/Carnivore	
Analyte	Mean	RME	Mean	RME	Mean	RME	Mean	RME	Mean	RME	Mean	RME
Ag	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	234.18	317.03	40.47	54.80	48.98	66.31	9.01	12.20	65.30	88.41	50.99	69.04
As	0.20	0.38	0.04	0.06	0.04	0.08	0.01	0.01	0.06	0.10	0.04	0.08
Ba	4.66	6.77	0.80	1.17	0.97	1.42	0.18	0.26	1.30	1.89	1.01	1.47
Be	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Cd	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co	0.16	0.23	0.03	0.04	0.03	0.05	0.01	0.01	0.05	0.07	0.04	0.05
Cr	0.19	0.26	0.03	0.05	0.04	0.06	0.01	0.01	0.05	0.07	0.04	0.06
Cu	1.60	4.59	0.28	0.79	0.33	0.96	0.06	0.18	0.45	1.28	0.35	1.00
Fe	312.06	410.30	53.94	70.92	65.27	85.81	12.01	15.79	87.02	114.42	67.96	89.35
Hg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K40	0.43	0.70	0.07	0.12	0.09	0.15	0.02	0.03	0.12	0.19	0.09	0.15
Mn	10.55	13.01	1.82	2.25	2.21	2.72	0.41	0.50	2.94	3.63	2.30	2.83
Mo	0.04	0.08	0.01	0.01	0.01	0.02	0.00	0.00	0.01	0.02	0.01	0.02
Ni	0.30	0.36	0.05	0.06	0.06	0.08	0.01	0.01	0.08	0.10	0.06	0.08
Pb	0.36	0.55	0.06	0.09	0.08	0.11	0.01	0.02	0.10	0.15	0.08	0.12
Ra226	0.49	1.69	0.09	0.29	0.10	0.35	0.02	0.07	0.14	0.47	0.11	0.37
Sb	0.08	0.17	0.01	0.03	0.02	0.04	0.00	0.01	0.02	0.05	0.02	0.04
Se	0.02	0.04	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01
Sn	0.05	0.08	0.01	0.01	0.01	0.02	0.00	0.00	0.01	0.02	0.01	0.02
Th232	0.05	0.12	0.01	0.02	0.01	0.03	0.00	0.00	0.01	0.03	0.01	0.03
Tl	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	0.49	1.14	0.08	0.20	0.10	0.24	0.02	0.04	0.14	0.32	0.11	0.25
V	2.91	9.40	0.50	1.62	0.61	1.97	0.11	0.36	0.81	2.62	0.63	2.05
Zn	1.39	1.89	0.24	0.33	0.29	0.39	0.05	0.07	0.39	0.53	0.30	0.41

Chemical intake for ingestion of contaminated soil and sediment was determined by applying the average soil ingestion rate to the exposure point concentration as follows:

Exposure Point Concentration (mg/kg)	x	Soil Ingestion Rate (kg/kg bw)	=	Chemical Intake (mg/kg bw/day)

Daily intakes of chemicals in surface water and soil are presented in Tables 4.5-12 and 4.5-13, respectively.

4.5.2.3 Preliminary Risk Characterization

Preliminary characterization of risk to passerine birds, raptors, small herbivores, small omnivores, and large herbivores was performed through the use of a hazard quotient approach. Hazard quotients were calculated by dividing daily chemical intakes (Tables 4.5-12 and 4.5-13) or surface water concentrations (Table 4.5-10) by benchmark values (Tables 4.5-4, 4.5-5, 4.5-6 and 4.5-7). Hazard quotients that exceed 1.0 indicate a potential for ecological risk. To obtain hazard preliminary quotients, the following comparisons were made (1) chemical intake from surface water to wildlife-specific benchmarks, (2) chemical intake from soil to wildlife-specific benchmarks, (3) surface water concentrations to Federal ambient water quality criteria, and (4) surface water concentrations to Utah State water quality standards. Hazard quotients from these comparisons are presented in Tables 4.5-14, 4.5-15, 4.5-16, and 4.5-17; the results are summarized below.

Surface Water Ingestion

Passerine

Incomplete toxicological or analytical data were available for aluminum, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, sulfate, antimony, tin, vanadium, and radionuclides.

Silver, beryllium, cadmium, and thallium were not detected in any surface-water samples. Preliminary hazard quotients were calculated for arsenic, barium, copper, mercury, lead, selenium, uranium, and zinc.

No preliminary hazard quotient exceeded 1.0.

Raptor

Incomplete toxicological or analytical data were available for aluminum, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, sulfate, antimony, tin, vanadium, and radionuclides.

Silver, beryllium, cadmium, and thallium were not detected in any surface water samples.

Preliminary hazard quotients were calculated for arsenic, barium, copper, mercury, lead, selenium, uranium, and zinc.

Table 4.5-15. Preliminary Hazard Quotients Based on Soil Ingestion

	Passerine			Raptor			Small herbivore			Large herbivore			Small Omnivore/Carnivore		
Analyte	TBV	Avg. HQ	RME HQ	TBV	Avg. HQ	RME HQ	TBV	Avg. HQ	RME HQ	TBV	Avg. HQ	RME HQ	TBV	Avg. HQ	RME HQ
Ag	NA	NA	NA	NA	NA	NA	65	0.00	0.00	65	0.00	0.00	65	0.00	0.00
Al	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
As	14	0.01	0.03	14	0.00	0.00	3.8	0.01	0.02	2	0.00	0.01	3.8	0.01	0.03
Ba	1000	0.00	0.01	1000	0.00	0.00	5.1	0.19	0.28	5.1	0.04	0.05	5.1	0.25	0.37
Be	NA	NA	NA	NA	NA	NA	0.54	0.01	0.01	0.54	0.00	0.00	0.54	0.01	0.01
Cd	0.2	0.03	0.08	0.2	0.00	0.01	2.5	0.00	0.00	0.002	0.11	0.31	2.5	0.00	0.00
Co	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cu	29	0.06	0.16	29	0.01	0.03	36	0.01	0.03	0.4	0.15	0.44	36	0.01	0.04
Fe	NA	NA	NA	NA	NA	NA	100	0.65	0.86	100	0.12	0.16	100	0.87	1.14
Hg	0.018	0.03	0.05	0.018	0.01	0.01	0.18	0.00	0.00	0.18	0.00	0.00	0.18	0.00	0.00
K40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mn	NA	NA	NA	NA	NA	NA	290	0.01	0.01	80	0.01	0.01	290	0.01	0.01
Mo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ni	NA	NA	NA	NA	NA	NA	24.15	0.00	0.00	24.15	0.00	0.00	24.15	0.00	0.00
Pb	14.5	0.02	0.04	14.5	0.00	0.01	0.3	0.25	0.38	1.2	0.01	0.02	0.3	0.33	0.51
Ra226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Se	0.088	0.18	0.51	0.088	0.03	0.09	0.057	0.06	0.16	0.08	0.01	0.02	0.057	0.08	0.22
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	0.237	0.02	0.05	0.237	0.00	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA
U	86	0.01	0.01	86	0.00	0.00	2.8	0.04	0.08	2.8	0.01	0.02	2.8	0.05	0.11
V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn	0.17	8.18	11.10	0.17	1.41	1.92	75	0.00	0.01	40	0.00	0.00	75	0.01	0.01

TBV = toxicity benchmark value, mg/kg bw-day, see Table 4.5-4.
HQ = hazard quotient

Table 4.5-16. Preliminary Hazard Quotients Based on Federal Ambient Water Quality Standards

	HQ Based on EPA Acute AWQC						HQ Based on EPA Chronic AWQC					
	Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient	
Analyte	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al	0.58	1.93	0.59	1.81	1.34	4.73	4.98	16.67	5.09	15.63	11.57	40.80
As	0.01	0.03	0.39	3.47	0.01	0.04	0.02	0.06	0.73	6.58	0.01	0.08
Ba	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Be	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ca	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	NA	NA	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND
Cr	0.00	0.00	ND	ND	0.00	0.02	0.02	0.02	ND	ND	0.02	0.13
Cu	0.56	0.56	0.36	3.62	0.14	0.59	0.84	0.84	0.53	5.43	0.21	0.89
Fe	NA	NA	NA	NA	NA	NA	No	Yes	No	Yes	Yes	Yes
Hg	ND	ND	0.08	0.08	ND	ND	ND	ND	16.67	16.67	ND	ND
Mn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Na	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ni	0.00	0.01	0.00	0.01	0.00	0.01	0.03	0.08	0.03	0.07	0.04	0.07
NO3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb	0.02	0.30	0.01	0.06	0.03	0.08	0.59	7.66	0.38	1.59	0.66	2.03
SO4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb	0.01	0.02	0.01	0.03	0.01	0.02	0.03	0.07	0.03	0.07	0.02	0.06
Se	0.11	0.49	1.90	27.00	0.12	0.98	0.44	1.94	7.60	108.00	0.46	3.92
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
U	0.00	0.01	0.07	0.36	0.01	0.06	0.00	0.01	0.07	0.36	0.01	0.06
V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn	0.10	0.28	0.10	0.32	0.21	0.72	0.11	0.31	0.11	0.35	0.22	0.79
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.5-17. Preliminary Hazard Quotients Based on Utah State Water Quality Standards

	HQ Based on Utah State Acute Criteria						HQ Based on Utah State Chronic Criteria					
	Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient	
Analyte	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al	0.58	1.93	0.59	1.81	1.34	4.73	4.98	16.67	5.09	15.63	11.57	40.80
As	0.01	0.03	0.39	3.47	0.01	0.04	0.02	0.06	0.73	6.58	0.01	0.08
Ba	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Be	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ca	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr	0.00	0.00	ND	ND	0.00	0.02	0.02	0.02	ND	ND	0.02	0.13
Cu	0.56	0.56	0.36	3.62	0.14	0.59	0.84	0.84	0.53	5.43	0.21	0.89
Fe	0.72	1.67	0.48	1.40	1.00	4.45	0.72	1.67	0.48	1.40	1.00	4.45
Hg	ND	ND	0.08	0.08	ND	ND	ND	ND	16.67	16.67	ND	ND
Mn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Na	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ni	0.00	0.01	0.00	0.01	0.00	0.01	0.03	0.08	0.03	0.07	0.04	0.07
NO3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Se	0.11	0.49	1.90	27.00	0.12	0.98	0.44	1.94	7.60	108.00	0.46	3.92
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn	0.10	0.28	0.10	0.32	0.21	0.72	0.11	0.31	0.11	0.35	0.22	0.79
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

The preliminary hazard quotient for selenium exceeded 1.0.

Small Herbivore

Incomplete toxicological or analytical data were available for aluminum, cobalt, chromium, molybdenum, nitrate, sulfate, antimony, tin, vanadium, and radionuclides.

Silver, beryllium, cadmium, and thallium were not detected in any surface-water samples. Preliminary hazard quotients were calculated for arsenic, barium, copper, iron, mercury, manganese, nickel, lead, selenium, uranium, and zinc.

No preliminary hazard quotient exceeded 1.0.

Small Omnivore

Incomplete toxicological or analytical data were available for aluminum, cobalt, chromium, molybdenum, nitrate, sulfate, antimony, tin, vanadium, and radionuclides.

Silver, beryllium, cadmium, and thallium were not detected in any surface water samples.

Preliminary hazard quotients were calculated for arsenic, barium, copper, iron, mercury, manganese, nickel, lead, selenium, uranium, and zinc.

The preliminary hazard quotients for selenium exceeded 1.0.

Large Herbivore

Incomplete toxicological or analytical data were available for aluminum, cobalt, chromium, molybdenum, nitrate, sulfate, antimony, tin, vanadium, and radionuclides.

Silver, beryllium, cadmium, and thallium were not detected in any surface water samples.

Preliminary hazard quotients were calculated for arsenic, barium, copper, iron, mercury, manganese, nickel, lead, selenium, uranium, and zinc.

No preliminary hazard quotient exceeded 1.0.

Soil Ingestion

Passerine

Incomplete toxicological or analytical data were available for silver, aluminum, beryllium, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, antimony, tin, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for arsenic, barium, cadmium, copper, mercury, lead, selenium, thallium, uranium, and zinc.

The preliminary hazard quotient for zinc exceeded 1.0.

Raptor

Incomplete toxicological or analytical data were available for silver, aluminum, beryllium, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, antimony, tin, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for arsenic, barium, cadmium, copper, mercury, lead, selenium, thallium, uranium, and zinc.

The preliminary hazard quotient for zinc exceeded 1.0.

Small Herbivore

Incomplete toxicological or analytical data were available for silver, aluminum, beryllium, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, antimony, tin, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, arsenic, barium, beryllium, cadmium, copper, iron, mercury, manganese, nickel, lead, selenium, uranium, and zinc.

No preliminary hazard quotient exceeded 1.0.

Small Omnivore

Incomplete toxicological or analytical data were available for silver, aluminum, beryllium, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, antimony, tin, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, arsenic, barium, beryllium, cadmium, copper, iron, mercury, manganese, nickel, lead, selenium, uranium, and zinc.

The preliminary hazard quotient for iron exceeded 1.0.

Large Herbivore

Incomplete data were available for silver, aluminum, beryllium, cobalt, chromium, iron, manganese, molybdenum, nitrate, nickel, antimony, tin, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, arsenic, barium, beryllium, cadmium, copper, iron, mercury, manganese, nickel, lead, selenium, uranium, and zinc.

No preliminary hazard quotient exceeded 1.0.

Federal Ambient Water Quality Criteria

Acute Standard

Incomplete data were available for barium, cobalt, iron, manganese, nitrate, molybdenum, tin, sulfate, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, aluminum, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, uranium, and zinc.

Hazard preliminary quotients for aluminum, arsenic, copper, and selenium exceeded 1.0.

Chronic Standard

Incomplete data were available for barium, cobalt, manganese, nitrate, molybdenum, tin, sulfate, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, mercury, nickel, lead, selenium, thallium, uranium, and zinc.

Hazard preliminary quotients for arsenic, aluminum, copper, iron, lead, and selenium exceeded 1.0.

Utah State Water Quality Standards

Acute Standard

Incomplete data were available for barium, beryllium, cobalt, manganese, molybdenum, nitrate, sulfate, antimony, tin, uranium, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, aluminum, arsenic, chromium, copper, iron, nickel, lead, selenium, zinc.

Hazard preliminary quotients for aluminum, arsenic, copper, iron, and selenium exceeded 1.0.

Chronic Standard

Incomplete data were available for barium, beryllium, cobalt, manganese, molybdenum, nitrate, sulfate, antimony, tin, uranium, vanadium, and radionuclides.

Preliminary hazard quotients were calculated for silver, aluminum, arsenic, chromium, copper, iron, nickel, lead, selenium, zinc.

Hazard preliminary quotients for aluminum, arsenic, copper, iron, mercury, lead, and selenium exceeded 1.0.

On the basis of the preliminary calculations, few contaminants pose risk to terrestrial receptors. Preliminary hazard quotients for selenium in surface water and for zinc and iron in soils exceeded 1.0. It is uncertain whether radionuclides and metals for which insufficient data were available pose risk to terrestrial receptors. Additionally, because detection limits for mercury and silver exceeded water quality criteria, it is uncertain whether these contaminants pose risk to terrestrial organisms.

Aquatic receptors may be at risk from elevated aluminum, arsenic, copper, iron, selenium, mercury, and lead concentrations in Montezuma Creek. It is uncertain whether radionuclides and metals for which insufficient data were available pose risk to aquatic receptors.

The results of the preliminary calculations indicate that risk to organisms in OU III probably is relatively low. While risk may have been underestimated because toxicity benchmark values were not available for all the preliminary COPCs, many of the methods used in this screening effort were conservative. For example, area use factors, bioavailability of COPCs, and metabolism and/or elimination of COPCs by receptors were not considered in the screening calculations.

4.5.3 Problem Formulation

Problem formulation involves re-evaluating and finalizing the preliminary conceptual site model, assessment and measurement endpoints, and COPCs, as well as stating testable hypotheses for the ecological risk assessment.

4.5.3.1 Conceptual Site Model

Two exposure pathways that were presented in the preliminary conceptual site model (Figure 4.5-3) were eliminated from the conceptual site model for OU III. Inhalation of COPCs in air was eliminated because millsite-related contaminants have not been detected by previous air sampling efforts (see Section 3.4, Air Investigations). Ingestion of contaminated ground water was eliminated because hydrogeological reconnaissance efforts (see Section 3.2.1) that were conducted to support the ground-water model did not reveal ground-water seeps within the OU III study area of sufficient continuous flow to form complete exposure pathways for OU III ecological receptors. If seeps of sufficient flow are found during field investigations, the seeps will be sampled and added to the conceptual site model. The revised conceptual site model is presented in Figure 4.5-4.

4.5.3.2 Assessment and Measurement Endpoints

On the basis of discussions with EPA's Ecological Technical Assistance Group (ETAG), protection of the golden eagle was eliminated as an assessment endpoint. This endpoint was replaced with protection of the deer mouse. This change was made because the deer mouse has a small home range and therefore is much more likely than the golden eagle to be exposed to contaminants within OU III. Measurement endpoints for the deer mouse include measuring COPC concentrations in surface water, soil, perennial grasses, forbs, and terrestrial invertebrates.

Under the assessment endpoint, "Protection of southwestern willow flycatcher and spotted bat populations from deleterious effects associated with elevated concentrations of metals and radionuclides," the measurement endpoint that specifies that cliff swallow liver/kidney samples will be analyzed will be changed to specify that cliff swallow liver samples and whole-body samples will be analyzed. This endpoint was changed because analytical laboratories require relatively large sample mass (approximately 200 grams) for radionuclide analysis of biota samples;

collection of the large numbers of cliff swallows required to obtain needed sample is not appropriate considering the limited number of cliff swallow nests that have been observed during preliminary site reconnaissance.

Table 4.5-18 presents the revised list of assessment and measurement endpoints.

Table 4.5-18. Assessment and Measurement Endpoints for OU III.

Assessment Endpoint	Measurement Endpoint(s)
Protection of mule deer populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of COPCs in shrubs. • Measure concentrations of COPCs in perennial grasses. • Measure concentrations of COPCs in forbs. • Measure concentrations of COPCs in surface water and soils.*
Protection of southwestern willow flycatcher and spotted bat populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of COPCs in cliff swallow nestlings (liver) as a surrogate for southwestern willow flycatcher and spotted bat. • Measure concentrations of COPCs in terrestrial invertebrates to estimate dietary dose received by spotted bat and southwestern willow flycatcher. • Conduct histopathology analysis on cliff swallow nestling (liver, kidney) to determine pathological changes.* • Conduct population surveys to document southwestern willow flyercatcher and spotted bat occurrence.
Protection of peregrine falcon populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of COPCs in cliff swallow nestlings (whole body) to represent dietary intake of peregrine falcons. • Conduct population surveys to document peregrine falcon occurrence. • Measure concentrations of COPCs in surface water and soils.*
Protection of deer mouse populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of COPCs in terrestrial invertebrates, grasses, and forbs. • Measure concentrations of COPCs in surface water and surface soils.*
Protection of muskrat populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of COPCs in grasses and shrubs. • Measure concentrations of COPCs in surface water and sediment.*
Protection of aquatic prey species populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Measure concentrations of COPCs in surface water and sediment. • Measure concentrations of COPCs in benthic invertebrates.
Protection of Montezuma Creek fish populations and San Juan River endangered fish populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	• Compare measured water and sediment concentrations from Montezuma Creek and estimated water and sediment concentrations from the San Juan River to benchmark ecotoxicity data to determine whether concentrations are harmful to fish. • Conduct population surveys for fish in Montezuma Creek.

*Ingestion of ground water from seeps will be included as an exposure parameter if seeps of sufficient volume to allow wildlife to drink are found along Montequma Creek.

4.5.3.3 Chemicals of Potential Concern

The preliminary COPC list (Table 4.5-2) was compiled from analyte lists from various previous investigations and from analytes on priority pollutant lists for which site data do not exist. Frequency of detection and site-relatedness were not always considered when previous analyte lists were compiled. To maximize the usability of data collected for the OU III risk assessments, a COPC screening was conducted. This screening involved comparisons of chemical concentrations to a site contamination model, to regional background data, and to human health and ecological toxicity benchmark values. Appendix E contains a detailed explanation of the screening methods and results. Ecological COPCs are presented in Table 4.5-19.

Table 4.5-19. Chemicals of Potential Concern for the OU III Ecological Risk Assessment

Chemical of Potential Concern	
Metals	**Radionuclides**
Aluminum	Gross Alpha
Arsenic	Gross Beta
Cobalt	Gross Gamma
Copper	Lead-210
Molybdenum	Radium-226
Nitrate	Thorium-230
Selenium	Uranium-234
Sodium	Uranium-235
Sulfate	Uranium-238
Tin	
Vanadium	
Zinc	

Specific radioisotope concentrations in abiotic media will be related to the gross radioactivity levels in biotic media by estimating the gross radioactivity of each of the specific radioisotopes.

4.5.3.4 Testable Hypotheses

On the basis of the results of the preliminary site calculations, the following hypotheses were formulated:

1. Metal concentrations in tissues of focused study area receptors (i.e., plants, cliff swallows, terrestrial invertebrates, or benthic macroinvertebrates) are similar to metal concentrations in tissues of background terrestrial receptors.

2. Gross radioactivity levels in tissues of focused study area receptors are similar to gross radioactivity levels in tissues of background terrestrial and aquatic receptors.

Section 4.5.4.1, Data Quality Objectives, presents the specific questions that will be asked to test these hypotheses. Section 4.5.4.2, Field Program, presents the sampling and survey methods that will be used to answer these specific questions.

4.5.4 Study Design

The ecological risk assessment study was designed to address the overall objectives of the RI as stated in Section 1.1. The following section discusses (1) the DQO process as it applies to the ecological risk assessment (Section 4.5.4.1), (2) the field sampling and ecological survey program (Section 4.5.4.2), and (3) the analytical methodology and detection limits for abiotic and biotic samples (Section 4.5.4.3).

4.5.4.1 Data Quality Objectives

The general steps of the DQO process described in Section 4.1 were implemented to identify specific data needs for the ecological risk assessment. Relevant steps of the DQO process as it applies to the ecological risk assessment are discussed in this work plan as follows:

Step 1–State the Problem. The ETAG committee members involved in the DQO scoping for the OU III RI ecological risk assessment included EPA, Utah Division of Wildlife Resources, Utah Department of Environmental Quality, and DOE.

Problem formulation for the OU III ecological risk assessment is the result of meetings and consensus between ETAG committee members. Sections 4.5.1.3 and 4.5.3 provide discussions of the rationale used in problem formulation.

The assessment endpoints identified in Section 4.5.3.2 are the basis for establishing data needs. A separate assessment endpoint is identified for each abiotic and biotic medium of concern for the ecological risk assessment, as shown in Figures 4.5-5 through 4.5-14, and Tables 4.5-20 through 4.5-29. For each assessment endpoint, specific objectives are identified.

Step 2–Identify the Decision. Decisions to be made on the basis of the data obtained are depicted as questions framed in diamonds in the decision flow diagrams (Figures 4.5-5 through 4.5-14). The same questions appear under the "Decision" heading in Tables 4.5-20 through 4.5-29. One or more decisions may be identified for each objective, and, in some cases, decisions represent the measurement endpoints identified in Section 4.5.3.2. The relationship between the decisions also is illustrated on the decision flow diagram.

Step 3–Identify Inputs to the Decision. Inputs to the decisions (shown on Tables 4.5-20 through 4.5-29) include existing and new sample analytical data, toxicological information, results of field ecological surveys, and modeled dietary intakes for biota. Analytical detection limits for

existing and new data are included under inputs because they must be considered when determining the adequacy of these data for decision making. Sources of data inputs as well as sampling and analytical techniques used for existing samples and proposed samples also are referenced in Tables 4.5-20 through 4.5-29.

Data action levels are the input criteria upon which decisions are based. Data action levels referred to in Tables 4.5-20 through 4.5-29 include (1) regulatory thresholds or standards (e.g., AWQC), (2) quantitative expressions of concentration goals (e.g., toxicity benchmark action levels), (3) background chemical concentration thresholds, and (4) reference area ecological survey results.

Step 4–Define the Study Boundaries. The spatial and temporal boundaries of investigative activities for the ecological risk assessment are identified in the final column of Tables 4.5-20 through 4.5-29. Figures illustrating existing or proposed sample locations (spatial boundaries) are referred to in these tables.

Optimal sampling times for biota (temporal boundaries) are identified in cases where sampling must occur during a specified time during the field season.

Step 5–Develop a Decision Rule. This step integrates the decision and data inputs resulting in statements of alternative actions. Alternative actions for each decision are shown on Figures 4.5-5 through 4.5-14.

Step 6–Specify Limits on Decision Errors. The purpose of this step is to help ensure that the quality of data is appropriate to make confident decisions. Confidence in decision making related to sample size is discussed in Section 4.5.4.2. Goals of 80 percent confidence and 90 percent power have been established for OU III. The numbers of samples required to meet these goals are presented in Table 4.5-30. Proposed numbers of samples of each medium that will be collected to address the assessment and measurement endpoints presented in Tables 4.5-31 and 4.5-32.

Step 7–Optimize the Design for Obtaining Data. The optimized design for the OU III ecological risk assessment investigation presented in this Work Plan was optimized through discussions of the alternatives with the ETAG.

Assessment Endpoint: Protection of aquatic prey species populations from potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Assessment Endpoint: Protection of Montezuma Creek fish populations and San Juan River endangered fish populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Assessment Endpoint: Protection of muskrat populations from potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Assessment Endpoint: Protection of terrestrial receptors (mule deer, southwestern willow flycatcher, spotted bat, peregrine falcon, and deer mouse from potential deleterious effects associated with elevated concentrations of metals and radionuclides in the surface-water.

Objective 1: Assess whether chemical concentrations are site-related.

Objective 2: Assess whether chemical concentrations in surface water are toxic to aquatic ecological receptors.

Objective 3: Assess whether elevated metal and radionuclide concentrations in surface water of Montezuma Creek are toxic to aquatic receptors in Montezuma Creek and endangered fish species in the San Juan River

Objective 4: Assess whether elevated metal and radionuclide concentrations in surface water of Montezuma Creek are toxic to terestrial receptors

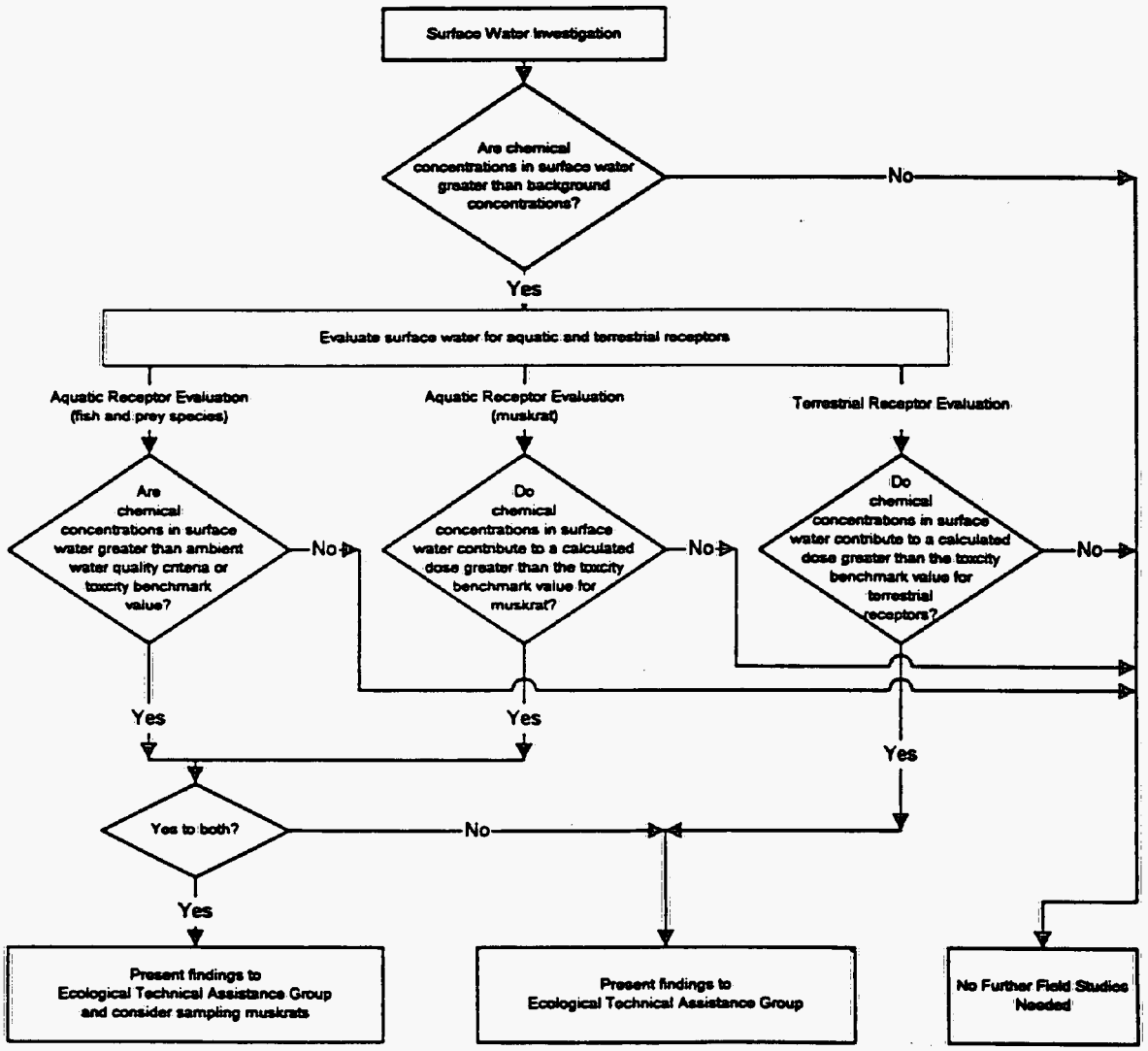


Figure 4.5-5. Surface-Water Investigation Decision Diagram

Assessment Endpoint: Protection of Montezuma Creek fish populations and San Juan River endangered fish populations from potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Assessment Endpoint: Protection of aquatic prey species populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Assessment Endpoint: Protection of muskrat populations from potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations are site-related.

Objective 2: Assess whether chemical concentrations in sediment are toxic to aquatic receptors.

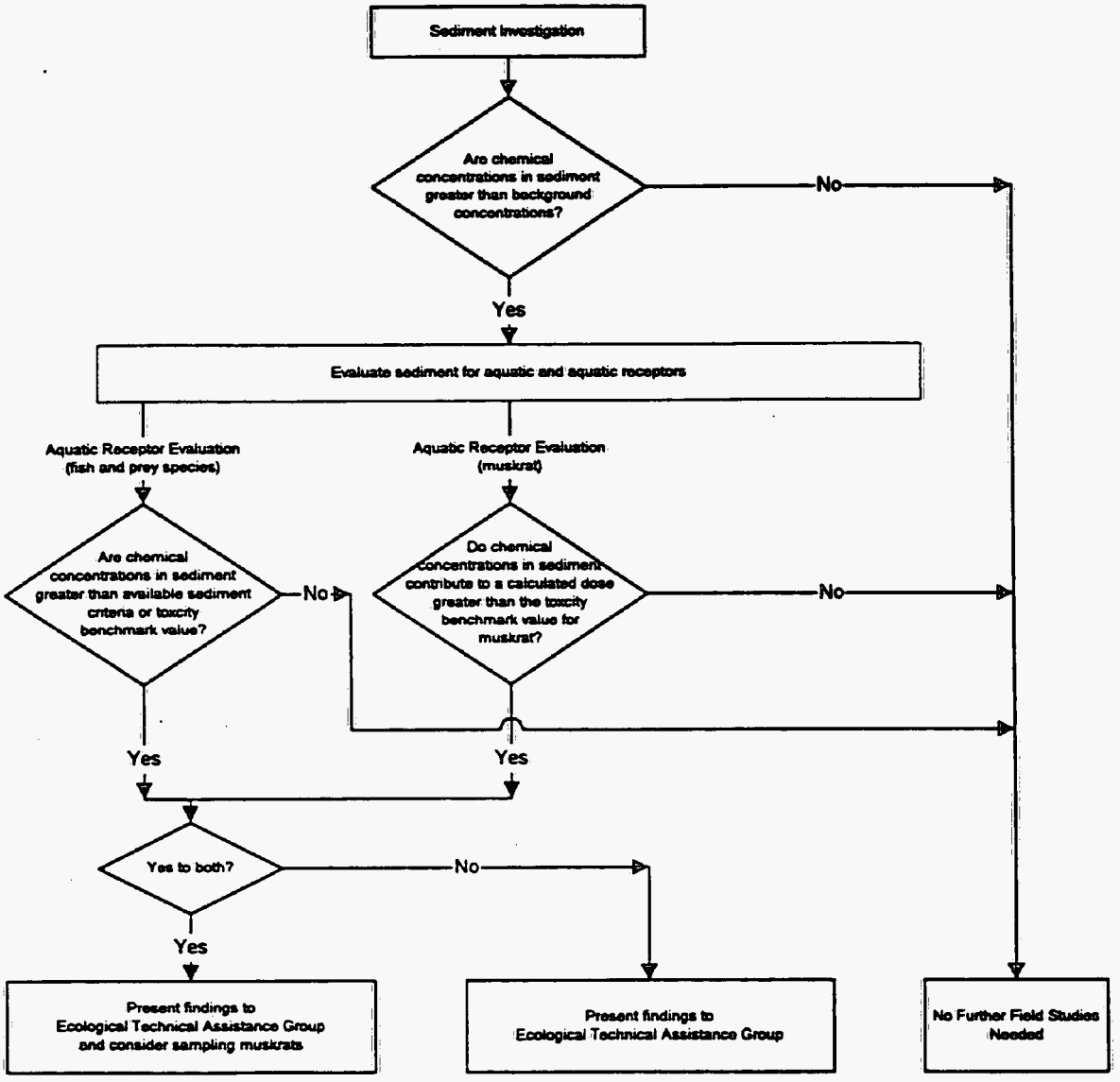


Figure 4.5-6. Sediment Investigation Decision Diagram

Assessment Endpoint: Protection of mule deer and deer mouse populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides in soil.

Objective 1: Assess whether chemical concentrations in soil are site-related.

Objective 2: Assess whether chemical concentrations in soil are toxic to terestrial ecological receptors (mule deer and deer mouse).

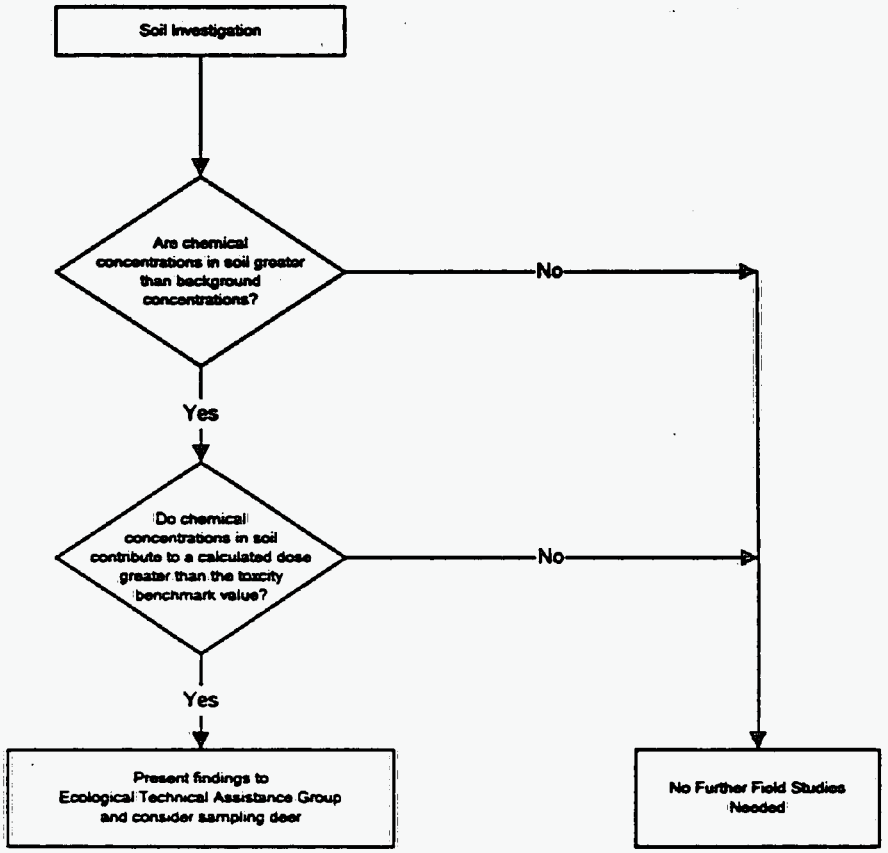


Figure 4.5-7. Soil Investigation Decision Diagram

Assessment Endpoint: Protection of mule deer, deer mouse, and muskrat populations from the potential deleterious effects associated with concentrations of elevated metals and radionuclides.

Objective 1: Assess whether chemical concentrations in collocated soil samples are site-related.

Objective 2: Assess whether chemical concentrations in perrenial grasses are site-related.

Objective 3: Assess whether rmodeled dietary doses exceed toxicity benchmark values.

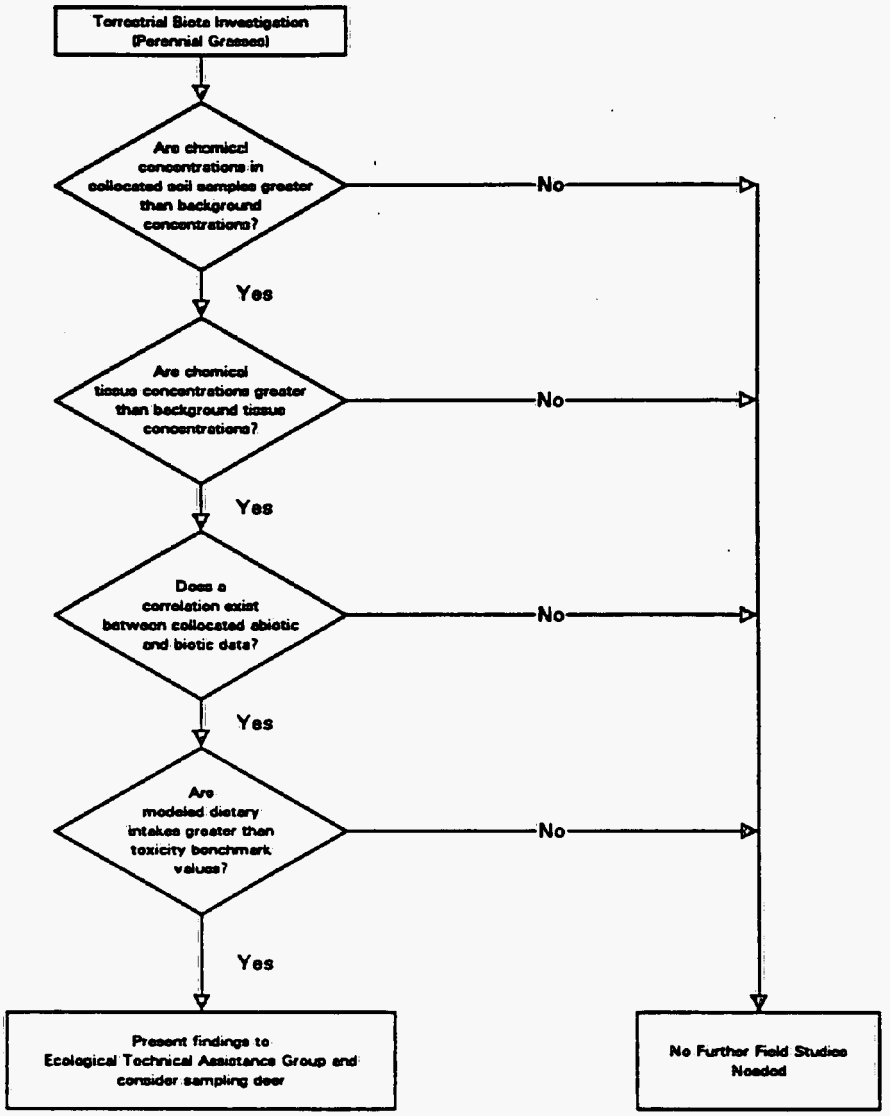


Figure 4.5-8. Terrestrial Biota Investigation — Prennial Grasses Decision Diagram

Assessment Endpoint: Protection of mule deer and deer mouse populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations in collocated soil samples are site-related.

Objective 2: Assess whether chemical concentrations in forbs are site-related.

Objective 3: Assess whether modeled dietary doses exceed toxicity benchmark values.

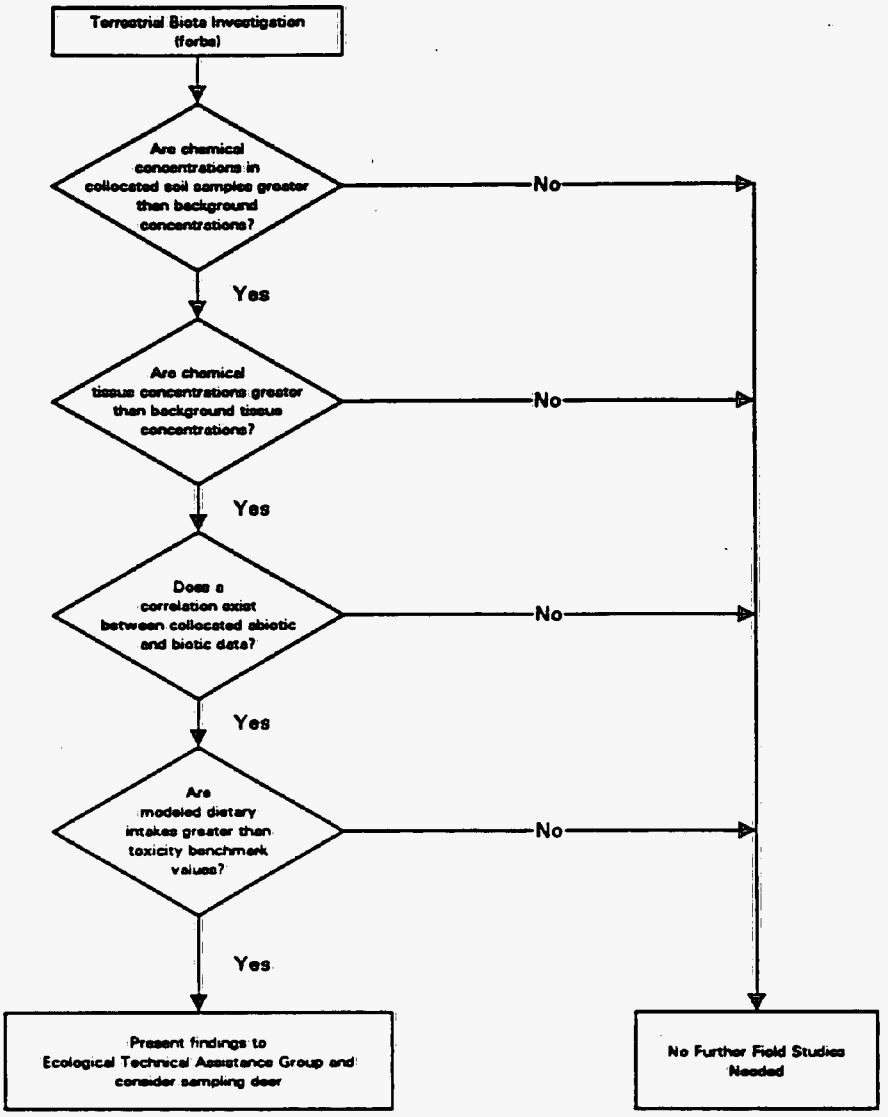


Figure 4.5-9. Terrestrial Biota Investigation — Forbs Decision Diagram

Assessment Endpoint: Protection of mule deer and muskrat populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations in collocated soil samples are site-related.

Objective 2: Assess whether chemical concentrations in shrubs are site-related.

Objective 3: Assess whether modeled dietary doses exceed toxicity benchmark values.

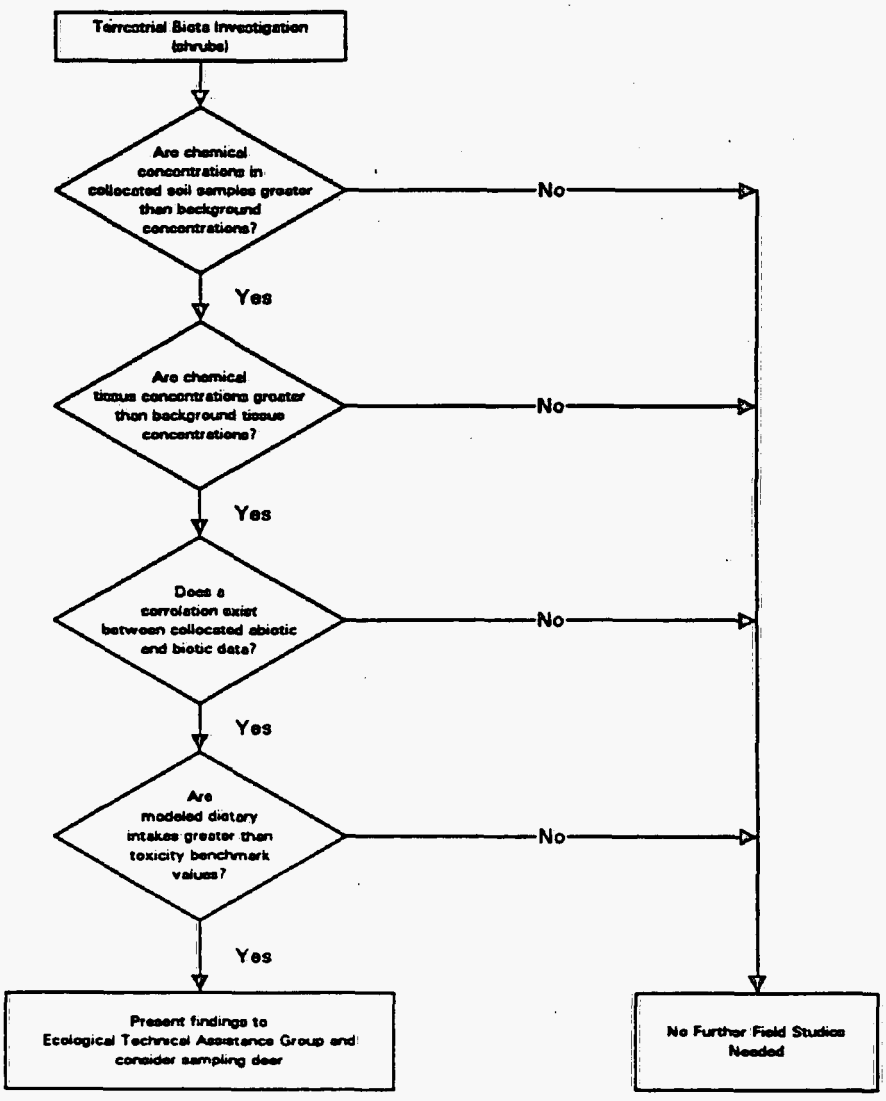


Figure 4.5-10. Terrestrial Biota Investigation — Shrubs Decision Diagram

Assessment Endpoint: Protection of deer mouse populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations in collocated soil samples are site-related.

Objective 2: Assess whether chemical concentrations in terrestrial invertebrates are site-related.

Objective 3: Assess whether modeled dietary doses exceed toxicity benchmark values.

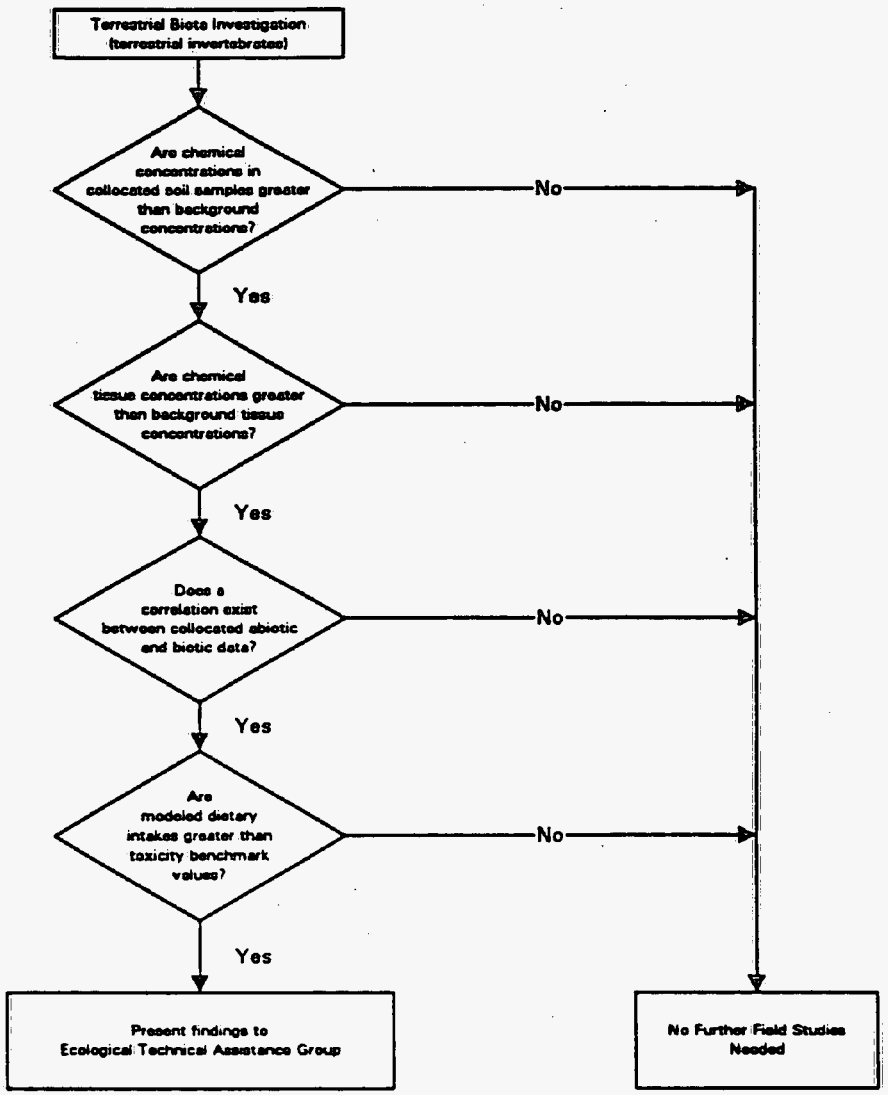


Figure 4.5-11. Terrestrial Biota Investigation — Terrestrial Invertebrates Decision Diagram

Assessment Endpoint: Protection of southwestern willow flycatcher and spotted bat populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations in cliff swallow nesting tissues (liver) samples are site-related.

Objective 2: Assess whether chemical concentrations in cliff swallow nesting tissue are indicative of impaired survivability or reproductive success of the southwestern willow flycatcher (a Category 1 species for federal listing as threatened or endangered) or the spotted bat (a Category 2 species for the federal listing as threatened or endangered).

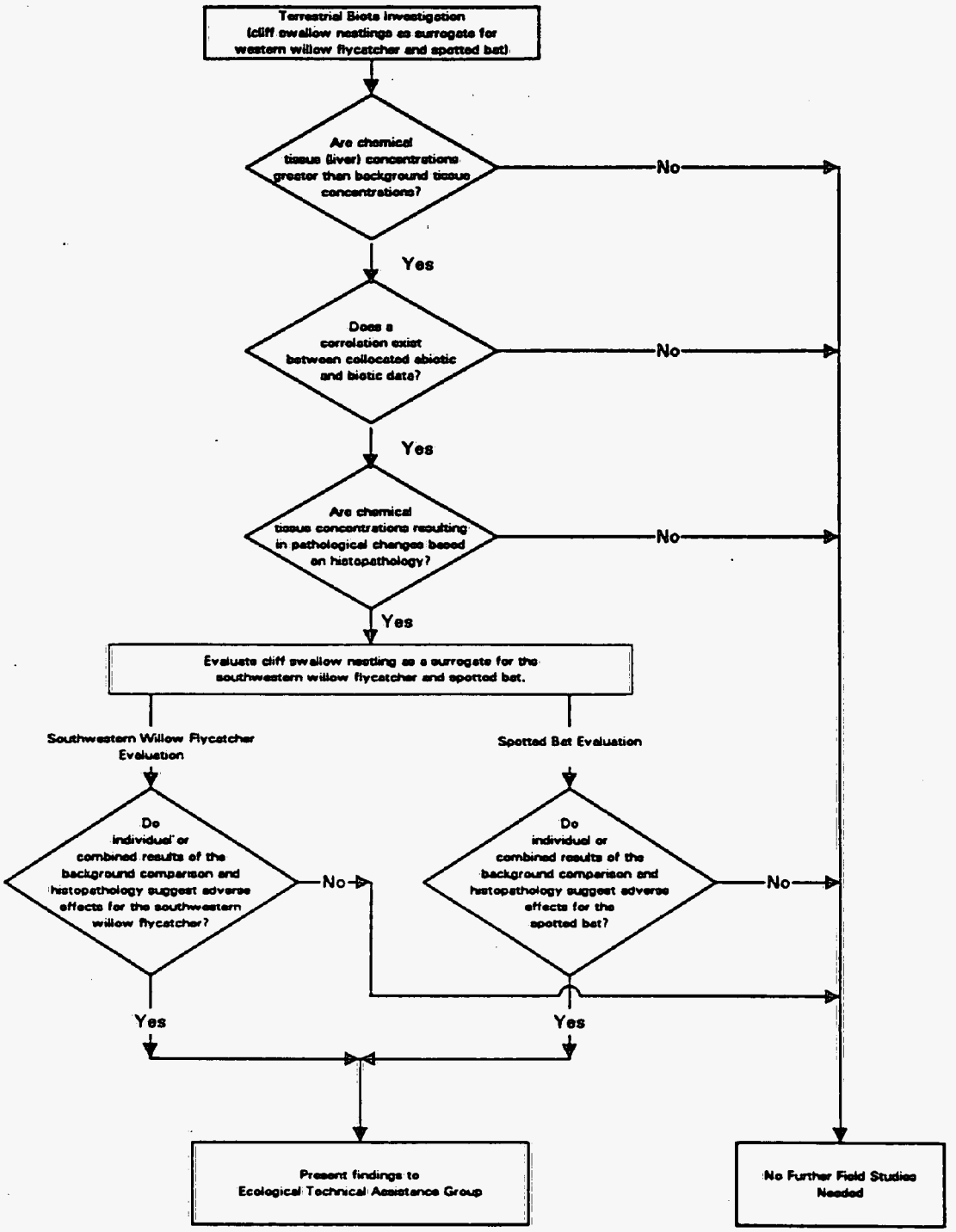


Figure 4.5-12. Terrestrial Biota Investigation — Cliff Swallow as Surrogate for Southwestern Willow Flycatcher and Spotted Bat Decision Diagram

Assessment Endpoint: Protection of peregrine falcon populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations in cliff swallow nestlings (whole body) are site-related.

Objective 2: Assess whether chemical doses to peregrine falcons exceeds toxicity benchmark values..

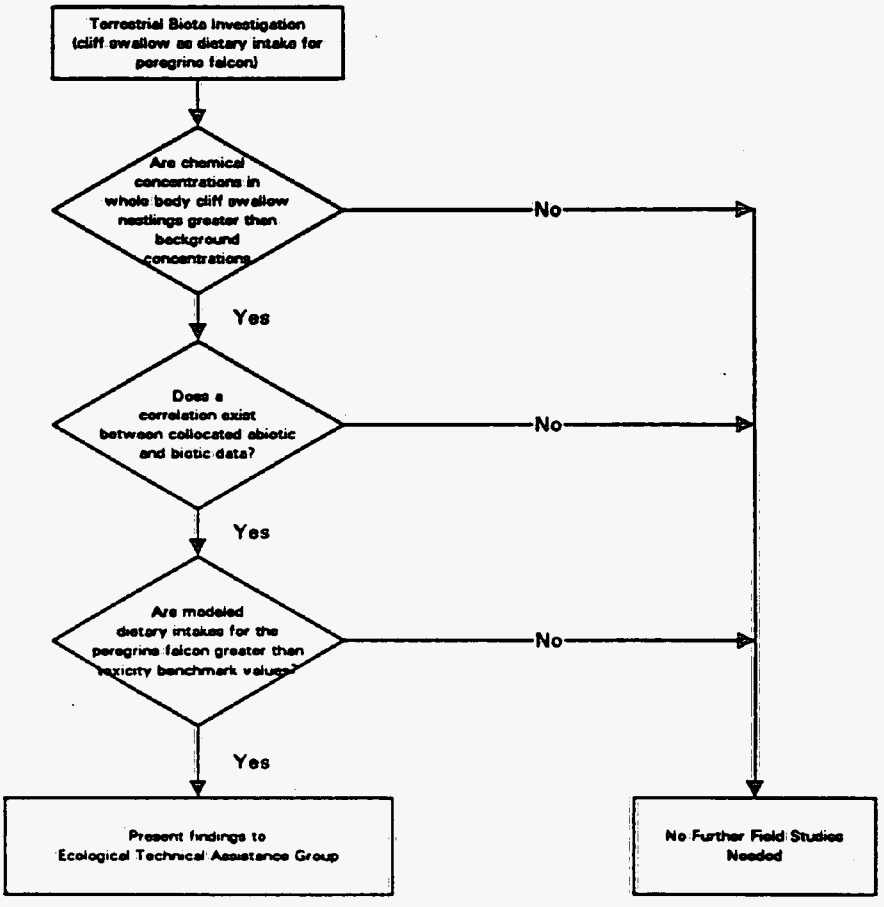


Figure 4.5-13. Terrestrial Biota Investigation — Cliff Swallow as Dietary Intake for Peregrine Falcon Decision Diagram

Assessment Endpoint: Protection of aquatic prey species populations from the potential deleterious effects associated with elevated concentrations of metals and radionuclides.

Objective 1: Assess whether chemical concentrations in collocated sediment samples are site-related.

Objective 2: Assess whether chemical concentrations in benthic macroinvertebrates are site-related.

Objective 3: Assess whether chemical concentrations in sediment, surface water, or tissues exceeds toxicity benchmark values.

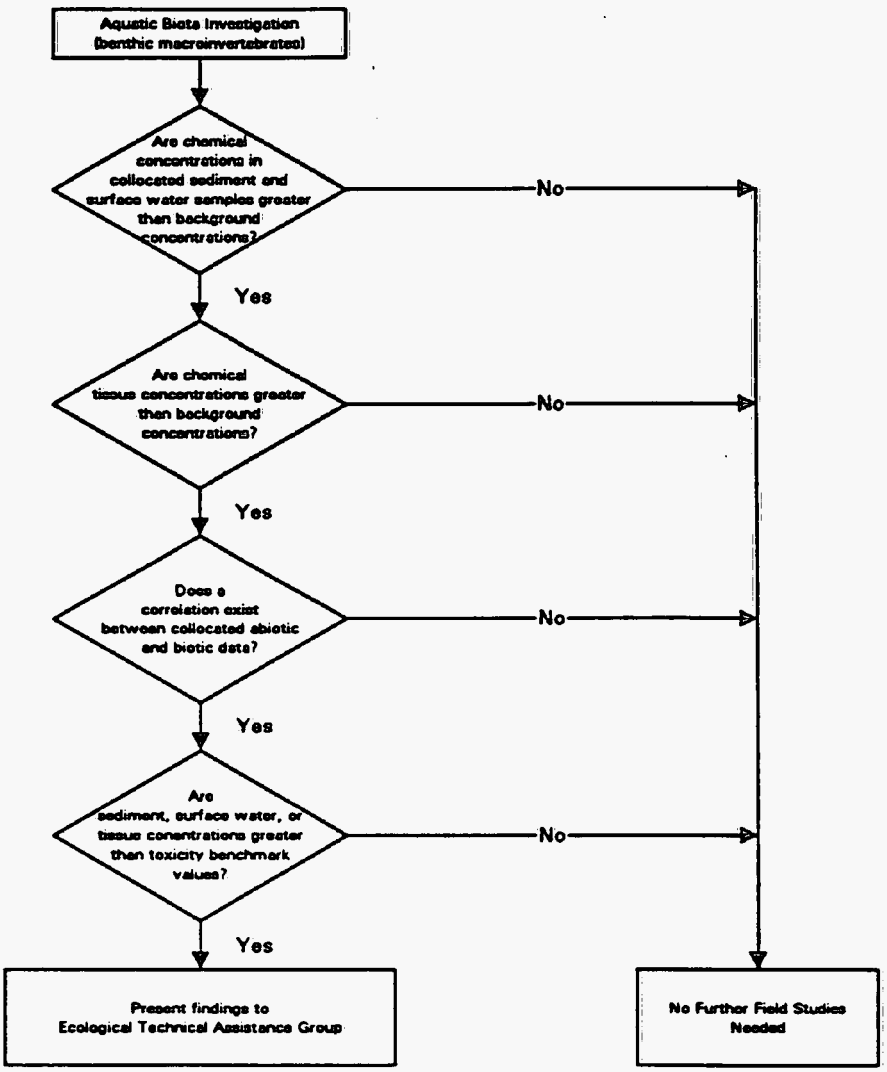


Figure 4.5-14. Aquatic Biota Investigation — Benthic Macroinvertebrates Decision Diagram

Table 4.5-30. Sample Size Based on Confidence of 80 Percent and Power of 90 Percent

CV (percent)	MDRD (percent)				
	5	10	20	30	40
10	19	5	2	1	1
15	41	11	3	2	1
20	73	19	5	3	2
25	114	29	8	4	3
30	163	41	11	5	3
35	222	56	15	7	4

CV Coefficient of variation
MDRD Minimum detectable relative difference
Note: This table will be used after data are collected to determine whether sample sizes were adequate to achieve goals of 80 percent confidence and 90 percent power.

The DQO process specified by EPA (EPA 1993b) is applied to the data requirements of the ecological risk assessment. The assessment endpoints, which determine the data needs of the risk assessment, are presented for each investigative medium. The measurement endpoints, which are quantifiable variables that address the assessment endpoints, are presented as decisions for which quantitative decision-making criteria (action levels) are available.

Because it is not certain that goals of statistical power and confidence will be met, answering the questions shown in Figures 4.5-5 through 4.5-14 and Tables 4.5-20 through 4.5-29 may not always be possible. As indicated in Figures 4.5-5 through 4.5-14, this does not trigger further field investigations. Rather, the data will be used qualitatively as part of a weight of evidence to support the decision process.

4.5.4.2 Field Program

The field program for the ecological risk assessment includes sampling of abiotic and biotic media, and conducting ecological surveys. This section discusses the general approach for sampling and survey activities; specific sampling methods for each abiotic and biotic medium and ecological survey methods are discussed in the Field Sampling Plan. Deviations from this sampling approach will be documented in field notes.

A judgmental or purposeful sampling design was proposed by DOE to obtain data for the ecological risk assessment. Judgmental sampling specifies sampling locations on the basis of existing site knowledge. This is appropriate when a risk assessment is performed using few samples (EPA 1992b).

*Table 4.5-31. Summary of Investigative Samples Collected for Chemical Analysis by Medium and Location**

Sample Location		Soil		Surface Water	Sediment	Forb	Shrub	Perennial Grass	Cliff Swallow		Benthic Invertebrate	Terrestrial Invertebrate
		Surface	Sub-surface						Liver	Remainder of Body		
Montezuma Transect	1	2	2	1	1	1	1	1			1	1
	2	2	2	1	1	1	1	1			1	1
	3	2	2	1	1	1	1	1			1	1
	4	2	2	1	1	1	1	1			1	1
	5	2	2	1	1	1	1	1	1	3	1	1
	6	2	2	1	1	1	1	1			1	1
	7	2	2	1	1	1	1	1			1	1
	8	2	2	1	1	1	1	1			1	1
	9	2	2	1	1	1	1	1			1	1
Montezuma Pond	1				10						1	
	2				10						1	
Verdure Transect	1	2	2	1	1	1	1	1			1	1
	2	2	2	1	1	1	1	1			1	1
	3	2	2	1	1	1	1	1			1	1
Vega Transect	1			1	1				1	3	1	
Medium Total		24	24	13	33	12	12	12	2	6	15	12
Sample Total												165

* Quality control samples are listed in Table A-5 of the OU III RI/FS Quality Assurance Project Plan

Table 4.5-32. Summary of Nonanalytical Data by Medium and Location

Sample Location		Fish Surveys	Bird Surveys	Bat Surveys	Cliff Swallow Histopathology (Liver, Kidney)
Montezuma Transects	1	X	X	X	
	2	X	X	X	
	3	X	X	X	
	4	X	X	X	
	5	X	X	X	3
	6	X	X	X	
	7	X	X	X	
	8	X	X	X	
	9	X	X	X	
Vega Transect					3
Medium Total					6

Judgmental sampling was considered the better design for the purposes of the risk assessment because if risks caused by source-related materials are evident, they will occur in areas with highest contaminant levels. Because effects must be quite strong to detect them when few samples are collected, it is best to collect data from the most heavily contaminated areas. The assumption behind this logic is that if no effects related to the source materials occur in the highly contaminated study areas, effects related to the source materials in other areas are unlikely.

Table 4.5-33 presents sample sizes required to meet the goals of 80-percent confidence and 90-percent power given different levels of minimum detectable relative difference (MDRD) and coefficient of variation (CV; the sample standard deviation divided by the sample mean). It is apparent that to maintain the stated goals of confidence and power, MDRD must be allowed to increase as the CV increases. Another way to view MDRD is that, when divided by the CV, it is equivalent to a pre-specified relative margin of error as described in Gilbert (Gilbert 1987). If the samples have large CVs, then either a greater margin of error must be acceptable, or the sample size must increase.

Table 4.5-33. Soil and Sediment Analytical Parameters, Methods of Analysis, and Method Detection Limits

Analytical Parameter[1]	Method of Analysis	Method Detection Limit
Metals		*mg/kg*
Aluminum	CLP Method 200.7	40.0
Arsenic	CLP Method 206.2	1.0
Cobalt	CLP Method 200.7	5.0
Copper	CLP Method 200.7	10.0
Molybdenum	CLP Method 200.7	10.0
Selenium	CLP Method 270.2	1.0
Tin	EPA SW-846 6020	2.0
Uranium[2]	Not Applicable	Not Applicable
Vanadium	CLP Method 200.7	5.0
Zinc	CLP Method 200.7	10.0
Radionuclides		*pCi/g*
Lead-210	Rust Method RC-6	2.0
Potassium-40	Rust Method GS-1	10.0
Radium-226	Rust Method GS-1	1.0
Thorium-230	EPA-SW846 6020[3]	1.0
Thorium-232	Rust Method GS-1	1.0
Uranium-234	EPA-SW846 6020[3]	1.0
Uranium-235	EPA-SW846 6020[3]	1.0
Uranium-238	EPA-SW846 6020[3]	1.0
Other		
Acid-Volatile Sulfide	To Be Determined	To Be Determined
Grain size analysis	ASTM D422	Measured to nearest whole percent
Moisture content	Rust Method SP-5	Measured to nearest tenth of a percent
Nitrate	EPA Method 300	2 mg/kg
pH	EPA Method 9040 modified	Measure to nearest hundredth of a unit
Sodium	CLP Method 200.7	50 mg/kg
Sulfate	EPA Method 300	2 mg/kg
Total organic carbon	Rust Method K-5	10.0 *mg/kg*

[1] COPCs are in bold-face type.

[2] Uranium isotopes will be measured rather than total uranium. Uranium is approximately composed of 99.3 percent Uranium-238.

[3] Method 6020 has been modified by the GJPO Analytical Laboratory for radionuclide analysis.

Sample Collection

Abiotic and biotic media will be sampled along nine sampling transects in the Montezuma Creek valley downstream of the OU II/OU III boundary (Figure 4.5-15 through Figure 4.5-22). These transects generally correspond to areas of high gamma activity on one side of the creek and low gamma activity on the other side of the creek (Bendix 1984, and DOE 1994). In addition to the nine Montezuma Creek transects, samples will be collected along four reference area transects, three in Verdure Creek canyon and one in Vega Creek canyon (Figure 4.5-1).

Each sampling transect has been established in the field by placing a survey stake at each end. Transects span the entire width of narrow sections of the canyon, or are sufficiently long to incorporate all major noncropland vegetation types in broad sections of the canyon.

Grasses, forbs, shrubs, terrestrial invertebrates, benthic invertebrates, soil, sediment, and surface water will be sampled along the nine Montezuma Creek transects and the three Verdure Creek transects. Additional sediment and benthic invertebrate samples will be collected from two ponds on Montezuma creek. Sediment, surface water, and benthic macroinvertebrates will be sampled along the Vega Creek transect. Cliff swallow samples have been collected from one Montezuma Creek transect and the Vega Creek transect.

On the basis of benthic invertebrate and vegetation analytical results, muskrats and deer may be sampled.

The numbers of samples for chemical analysis by medium and location are provided in Table 4.5-34. Table 4.5-35 provides information on additional data (e.g., ecological survey data and histopathological data) to be collected.

Table 4.5-34. Surface Water Analytical Parameters, Methods of Analysis, and Method Detection Limits

Analytical Parameters[1]	Method of Analysis	Method Detection Limit
Metals		µg/L
Aluminum	CLP Method 200.7	50
Arsenic	EPA SW-846 6020	5.0
Cobalt	CLP Method 200.7	10
Copper	CLP Method 200.7	5.0
Molybdenum	CLP Method 200.7	50
Selenium	EPA SW-846 6020	5.0
Tin	EPA SW-846 6020	5.0
Uranium	Not Applicable	Not Applicable

Table 4.5-34. Surface Water Analytical Parameters, Methods of Analysis, and Method Detection Limits (Continued)

Analytical Parameters[1]	Method of Analysis	Method Detection Limit
Vanadium	**CLP Method 200.7**	**10**
Zinc	**CLP Method 200.7**	**4.0**
Radionuclides		*pCi/L*
Gross Alpha	**Rust Method RC-3**	**1.0**
Gross Beta	**Rust Method RC-3**	**1.0**
Lead-210	**Rust Method RC-6**	**2.0**
Radium-226	**Rust Method RC-5**	**0.5**
Radon-222	**Rust Method RC-17**	**60.0**
Thorium-230	**EPA SW-846 6020[3]**	**1.0**
Uranium-234	**EPA SW-846 6020[3]**	**1.0**
Uranium-235	**EPA SW-846 6020[3]**	**1.0**
Uranium-238	**EPA SW-846 6020[3]**	**1.0**
Other		*mg/L*
Calcium	CLP Method 200.7	0.10
Magnesium	CLP Method 200.7	0.10
Nitrate	EPA Method 300	0.2
Sulfate	EPA Method 300	0.2

[1] COPCs are in bold-face type.

[2] Uranium isoltopes will be measured rather than total uranium. Uranium is approximately composed of 99.3 percent Uranium-258.

[3] Method 6020 has been modified by the GJPO Analytical Laboratory for radionuclide analysis.

Table 4.5-35. Biota Analytical Parameters, Methods of Analysis, and Method Detection Limits

Analytical Parameter[1]	Proposed Method of Analysis	Requested Method Detection Limit
Metals		mg/kg
Aluminum	CLP Method 200.7	1.0
Arsenic	CLP Method 206.2	1.0
Cobalt	CLP Method 200.7	5.0
Copper	CLP Method 200.7	1.0
Molybdenum	CLP Method 200.7	10.0
Selenium	CLP Method 270.2	1.0
Tin	EPA SW-846 6020	2.0
Vanadium	CLP Method 200.7	1.0
Zinc	CLP Method 200.7	10.0
Radionuclides		
gross alpha	———	5.0
gross beta	———	5.0
gross gamma	———	1.0

[1]All biota analytical parameters are chemicals of potential concern.

Ecological Surveys

Mule deer, muskrats, and deer mice are known to inhabit Montezuma Creek canyon. Population surveys will be conducted in Montezuma Creek canyon to document the presence or absence of the remaining receptors — southwestern willow flycatcher, spotted bat, peregrine falcon, and fish.

4.5.4.3 Analytical Program

Biota, soil, sediment, and surface water samples will be collected to support the ecological risk assessment (ERA). Biota will be analyzed for metals and gross alpha, beta, and gamma radioactivity. Soil, sediment, and surface water samples will be analyzed for metals and radionuclides. On the basis of calculations performed and conclusions drawn in the preliminary ERA (Section 4.5.4), a list of COPCs has been formulated and is presented in Tables 4.5-33, 4.5-34, and 4.5-35. Also contained in these tables are the method detection

limits (MDLs) which, on the basis of the ecotoxicity benchmarks for ecological risk characteriztion, must be attained so that the analytical data are adequate for ecological risk assessment use.

All abiotic media will be analyzed for metals and radionuclides. In addition, other measurements of physical or chemical parameters of soil and sediment, such as grain size, moisture content, pH, organic carbon content, and naturally occurring radionuclides analysis (radionuclides that are not part of the uranium decay series and not a component of uranium ore), are needed to support risk assessment. Additional surface water parameters include sulfate and nitrate concentrations and, to calculate water hardness, calcium and magnesium concentrations.

Samples of soil, sediment, and surface water will be submitted to the GJPO Analytical Laboratory for analysis. The CLP methodologies will be the primary methodologies used for metals analyses in sediment, soil, and surface water media. When TBVs require MDLs below what can be achieved by CLP-RAS, then other EPA methods (i.e., SW-846) will be substituted. Data deliverables will be similar to CLP-RAS.

Radionuclide analyses of samples collected in sediment, soil, and surface water will be by the GJPO Analytical Laboratory's standard methods and procedures. The analytical technique used to measure each of the radionuclide activities is presented in Table 4.5-36.

Table 4.5-36. Analytical Techniques for Radionuclides for Sediment, Soil, and Surface Water

Media	Analytical Technique					
	Liquid Scintillation Spectrometry	Gamma Spectrometry	Liquid Scintillation Counting	Proportional Counting	Alpha Spectrometry	Inductively Coupled Plasma Mass Spectrometry
Sediment and Soil	Lead-210	Potassium-40 Radium-226 Thorium-232				Uranium-234 Uranium-235 Uranium-238 Thorium-230
Surface Water	Lead-210		Radon-222	Gross Alpha Gross Beta	Radium-226	Uranium-234 Uranium-235 Uranium-238 Thorium-230

surrogate species, the cliff swallow. The exposure of fish in Montezuma Creek will be estimated by measuring surface water and sediment concentrations. The exposure of aquatic prey species will be estimated by measuring benthic macroinvertebrate, surface water, and sediment concentrations.

Biota samples collected during the RI to support the ERA will be submitted to a subcontracted laboratory for analysis. Grasses, forbs, shrubs, terrestrial invertebrates, benthic invertebrates,

and cliff swallows be analyzed for metals and gross radioactivity. Analytical methodologies may include those of the Association of Official Analytical Chemists (AOAC), EPA SW-846, EPA CLP Special Analytical Services, or combinations thereof. Data deliverables will exhibit a level of detail similar to that of EPA's CLP-Routine Analytical Services (RAS) deliverables.

In addition to the data obtained from the chemical analysis of samples, samples of cliff swallow liver and kidney will be obtained and submitted to a trained and experienced veterinary pathologist. Samples will be preserved in a 10-percent formalin solution. The nature of histopathological data precludes specifying an analytical method or detection limit.

Acceptance criteria for laboratory analyses, including calibration of laboratory equipment and internal laboratory QC checks (i.e., reagent blanks, duplicates, matrix spikes, matrix spike duplicates, etc.), are specified by the analytical method. Documentation is maintained for all analytical results as a means of supporting reported results and identifying potential causes for measurement problems. The FSP lists for each medium the determination method, method detection limit, requirements for sample containers, sample volume, preservation, and holding times. Holding times for analysis of metals and radionuclides in biota samples are not established. A minimum holding time of 6 months and a maximum holding time of 1 year until sample digestion are proposed if the samples are preserved correctly (i.e., frozen).

During analytical data review it will be verified that the laboratories performed the methods requested and followed method QA/QC. The data will be validated by reviewing raw data and supporting field and laboratory information to determine if they are of adequate quality for their intended purposes. Verification and validation forms will be prepared as a means of documenting the review process.

4.5.5 Risk Characterization

Risk characterization involves six steps: Exposure Assessment, Effects Assessment, Risk Description, Uncertainty Analysis, Risk Summary, and Interpretation of Ecological Significance. These steps are described below.

4.5.5.1 Exposure Assessment

Ecological survey data will be used to determine which receptors inhabit the OU III study area. Animals that are not found during surveys are not expected to have complete exposure pathways to OU III contaminants. However, some species that inhabit the OU III study area may not be documented by the surveys. Therefore, it will be assumed that the rare species (southwestern willow flycatcher, spotted bat, and peregrine falcon) inhabit the area even if they are not documented by the ecological surveys.

The analytical data collected in the site field investigation will be used to define exposure scenarios for ecological receptors in Montezuma Canyon. The spotted bat and southwestern willow flycatcher's exposure will be estimated by measuring the tissue concentrations in a surrogate species, the cliff swallow. The exposure of fish in Montezuma Creek will be estimated

by measuring surface water and sediment concentrations. The exposure of aquatic prey species will be estimated by measuring benthic macroinvertebrate, surface water, and sediment concentrations.

Exposure for the remaining receptors of concern (peregrine falcon, deer mouse, muskrat, and mule deer) will be estimated through dose calculations. Environmental media concentration data and conservative exposure factors will be used to estimate the contaminant dose received by each of these receptors.

The basic equation that will be used in the dose calculations is:

$$(1)\quad D_{receptor} = \{(Conc_{foodA})(\%Diet_{foodA})(IR_{food})(FI) + (Conc_{foodB})(\%Diet_{foodB})(IR_{food})(FI) +$$

$$(CS)(\%Diet_{soil})(IR_{food})(FI) + (CW)(IR_{water})(FI)\}/BW_{receptor}$$

where:

$D_{receptor}$	=	dietary dose to the receptor, in mg/kg/day;
$Conc_{foodA}$	=	contaminant concentration in food item A, in mg/kg;
$\%Diet_{foodA}$	=	percent of the receptor's diet consisting of food item A, in percent;
IR_{food}	=	receptor's ingestion rate for food, in kg/day;
FI	=	fraction of the receptor's ingestion that occurs in contaminated areas;
$Conc_{foodB}$	=	contaminant concentration in food item B, in mg/kg;
$\%Diet_{foodB}$	=	percent of the receptor's diet consisting of food item B, in percent;
CS	=	contaminant concentration in soil, in mg/kg;
$\%Diet_{soil}$	=	percent of the receptor's diet consisting of soil, in percent;
CW	=	contaminant concentration in Meandering Road Creek surface water, in mg/L;
Ir_{water}	=	receptor's ingestion rate for water, in L/day; and
$Bw_{receptor}$	=	receptor's body mass, in kg.

Doses will be calculated using mean and 95% UCL environmental media data. The following receptor-specific factors will be used in the general equation:

Peregrine Falcon

- Diet is assumed to be composed of 98 percent birds and 2.0 percent soil (based on lowest ingestion values in Beyer et al. 1994)
- Ingestion rate for food is 0.29 gram/gram body mass/day (0.0551 kg/day, EPA 1993e)
- Ingestion rate for water is 0.11 gram/gram body mass/day (0.0209 L/day, EPA 1993e)
- Fraction of ingestion from contaminated areas is 100 percent (35 hectare [87 acre] home range estimated from red-tailed hawk and American kestrel in EPA 1993c, 445 acre site)
- Body mass is 0.19 kg (estimated from American kestrel length [10.5 inches], National Geographic Society 1987, and body mass [125 grams], EPA 1993e)

Deer Mouse

- Diet is composed of 68.9 percent invertebrates, 29.1 percent plants, and 2.0 percent soil (DOE 1993c and Beyer et al. 1994)
- Ingestion rate for food is 0.0327 kg/day (DOE 1993c)

- Ingestion rate for water is 0.00357 L/day (DOE 1993c)
- Fraction of ingestion from contaminated areas is 100 percent (based on 0.5 acre home range, Burt and Grossenheider 1980, and 445 acre site.)
- Body mass is 0.021 kg (DOE 1993c)

Muskrat

- Diet is composed of 5 percent soil, 5 percent shrubs, 90 percent grasses (based on burrowing mammal soil ingesion in Beyer et al 1994, muskrat diet in EPA 1993e, and vegetation types in Section 4.5.1.1)
- Ingestion rate for food is 0.34 g/g/day (0.34 kg/day, EPA 1993e)
- Ingestion rate for water is 0.97 g/g/day (0.97 L/day, EPA 1993e)
- Fraction of ingestion from contaminated areas is 100 percent (60 m diameter home range, 445 acre site)
- Body mass is 1 kg (EPA 1993e)

Mule Deer

- Diet is assumed to be composed of 2 percent soil (Beyer et al. 1994), 16 percent grasses, 16 percent forbs, and 66 percent shrubs (estimated based on browse being dominant food type)

- Ingestion rate for food is 7.33 kg/d (based on ingestion rate of 4.39 for 59.9 kg deer, DOE 1993c)
- Ingestion rate for water is 4.55 l/day (based on water ingestion rate of 2.73 for 59.9 kg deer, DOE 1993c)
- Fraction of ingestion from contaminated areas is 74 percent (600 acre home range, Burt and Grossenheider 1980, 445 acre site)
- Body mass is 100 kg (estimated from Burt and Grossenheider 1980)

4.5.5.2 Effects Assessment

In the following paragraphs ecotoxicity profiles for the COPCs are presented, ecotoxicity benchmark values that will be used for risk characterization are derived, and the results of histopathological analyses are discussed.

Ecotoxicity Profiles

The ecotoxicity profiles in Section 4.5.2.1, Preliminary Ecotoxicity Profiles, have been expanded for the metals COPCs that will be considered for risk assessment. These profiles are presented below. Ecotoxicity data could not be found for gross alpha, beta, and gamma radioactivity.

Aluminum

Little aluminum is absorbed by the gut following ingestion; most is excreted with the feces (Seiler et al. 1988, and Thienes and Haley 1972). Of the aluminum that is absorbed, most is

deposited in the bones, which lowers levels of inorganic phosphorus in the bones, and can lead to rickets (Browning 1969, Thienes and Haley 1972). LD50 values for aluminum ingestion generally are unavailable for animals because death occurs from intestinal blockage from precipitated aluminum rather than from systemic aluminum poisoning (Seiler et al. 1988).

However, ingestion of aluminum at high concentrations absorbed doses that can cause lethargy, anorexia, or death (National Research Council 1981). The kidney is the primary organ that removes absorbed aluminum from the body (Kovalchik 1978).

Aluminum compounds have been evaluated as non-mutagenic by most standard mutagenicity assays (Friberg et al. 1986). However, Shepard's Catalog of Teratogenic Agents (Shepard 1995) reports that aluminum is mildly teratogenic, producing delayed postnatal development and lower learning acquisition in rats.

Long and Morgan (Long and Morgan 1990) do not report Effects Range-Low (ER-L) or Effects Range-Median (ER-M) concentrations for aluminum in sediments. Utah and Federal acute and chronic Ambient Water Quality Criteria (AWQC) are 750 μg/L and 87 μg/L, respectively.

Devilers and Exobrayat (Devilers and Exobrayat 1992) reported 96-hour LC50 values of 0.27 to greater than 1.762 mg/L for the toad, *Bufo americanus*, and 0.43 to greater than 1.018 mg/L for the frog, *Rana pipiens*. Suter reports a recommended ecotoxicity benchmark value of 10 mg/kg in soil (Suter el al. 1993). ICF Kaiser reports that 2500 to 2800 mg/kg in soil results in 55 to 75 percent survival in the wood louse over six to twelve weeks (ICF Kaiser 1989).

Arsenic

Arsenic causes internal swelling and hemorrhaging in cattle and fowl (Booth and McDonald 1982). Mitochondria are particularly vulnerable to inorganic arsenic, causing swelling and interference with heme production (Fowler 1971). Arsenic toxicity in aquatic microorganisms causes growth and metabolism to decline (NRCC 1978).

Shepard's Catalog of Teratogenic Agents (Shepard 1995) lists arsenic as teratogenic.

Long and Morgan report an ER-L of 33 ppm and an ER-M of 85 ppm in sediment (Long and Morgan 1990).

Utah and Federal acute and chronic Ambient Water Quality Criteria (AWQC) are 360 μg/L and 190 μg/L, respectively.

Toxic doses of 7.6 ppm (240 hour, bass), 11.6 ppm (36 hour, minnow) and 60 ppm (16 hour, minnow) were reported by OHM-TADS (1995). OHM-TADS (1995) reported oral LD50 concentrations of 6.5 mg/kg-bw for fowl and swine, 15-112 mg/kg-bw for rats, 25-47 mg/kg-

bw for mice, and 324 mg/kg-bw for chickens. LD50 values of 145 mg/kg-bw for mice and 763 mg/kg-bw for rats were reported (Gigiena Truda i Professional'nye Zabolevaniya 1987).

Whitworth reported a LOAEL value of 300 ppm for mallard duck behavior and growth (Whitworth et al, 1991). Schroeder reported a LOAEL value of 22.5 mg/kg-bw/day for rats (Schroeder et al. 1968).

Cobalt

Toxicity of ingested cobalt is dependent on overall diet. Rats did not tolerate cobalt in a milk-only diet. However, rats tolerated a daily dose of 1 mg/day in water for 14 weeks (Clayton and Clayton 1982). Young rats were unable to survive repeated 30 mg/day doses of cobalt metal powder in food, but they tolerated 1,250 mg in a single dose (Venugopal and Luckey 1978).

Shepard's Catalog of Teratogenic Agents (Shepard 1995) lists cobalt as embryotoxic (causing reduced fetal weight) at 50 mg/kg throughout gestation.

No Federal or Utah AWQC are listed for cobalt. Long and Morgan do not report ER-L or ER-M values for cobalt in sediment (Long and Morgan 1990).

Venugopal and Luckey listed the following LD100 values for cobalt: 150 mg/kg intraperitoneal dose to mice, 375 mg/kg intraperitoneal dose to rats, 100 mg/kg intravenous dose to rats, and 20 mg/kg intravenous dose to rabbits (Venugopal and Luckey 1978). An oral LD50 value of 6171 mg/kg was reported for rats (J. Am. Coll. Tox. 1992). The National Research Council reports that acute cobalt toxicity occurs only at high doses (i.e. 50 mg/kg-food/day in chickens). Under 5 mg/kg-food/day, no adverse effects were noted (NRCC 1977).

Copper

Copper is a trace metal that is essential to normal metabolism (TERIS 1995). It is not known to be teratogenic (Shepard 1995).

The Utah and Federal chronic AWQC is 1000 μg/l.

Long and Morgan report an ER-L of 70 ppm and an ER-M of 390 ppm in sediment (Long and Morgan 1990).

Many ecotoxicity data are available for fish. Reduced hatching of fathead minnows occurred at 621 μg/l but not at 330 μg/l (Scudder et al. 1988). LC50 values of 250 μg/l for a 96-hour bioassay and 123 μg/l for a 28-day bioassay were reported (Scudder 1988). Median Threshold Lethality (TLm) values of 0.43 to 0.47 were reported for 96-hour fathead minnow bioassays (OHM-TADS 1995). LC50 values for trout range from 0.01 to 0.8 ppm (OHM-TADS 1995).

Fewer data are available for terrestrial animals. Opresko reported NOAEL values of 29 mg/kg-body weight/day for mallard ducks and 22.8 mg/kg-body weight/day for chickens (Opresko et al. 1993). Suttle and Mills reported a LOAEL value of 36 mg/kg-body weight/day for rats (Suttle and Mills 1966).

Molybdenum

Excessive dietary molybdenum interferes with the metabolism of calcium and phosphorus, inducing osteoporosis, lameness, bone/joint abnormalities, and connective tissue changes (Venugopal and Luckey 1978). 2-100 mg/kg of molybdenum in feed causes diarrhea, weight loss, infertility, anemia, or death in livestock (NRCC 1982, Venugopal and Luckey 1978). No Federal or Utah AWQC are listed for molybdenum. Long and Morgan (1990) do not report ER-L or ER-M values for molybdenum in sediment.

Molybdenum is an essential trace metal (TERIS 1995). It is less toxic in the presence of copper (Smythe 1982, TERIS 1995). Shepard's Catalog of Teratogenic Agents (Shepard 1995) lists molybdenum as teratogenic; it causes reduced fetal weight and post-natal runting.

NOAEL values of 2400 and 7500 ppm were reported for bluegill sunfish and channel catfish, respectively. LC50 values of 6500 to 10,000 were reported for bluegill sunfish and channel catfish. (OHM-TADS 1995). LD50 values for rats range from 101 to 333 mg/kg-body weight/day (OHM-TADS 1995).

Nitrate

Nitrate is not listed as teratogenic in TERIS or Shepherd's Catalog of Teratogenic Agents (TERIS 1995 and Shepard 1995). AWQC and Long and Morgan ER-L and ER-M values are not available.

IRIS reported human NOAEL and LOAEL values of 2 and 20 mg/kg-body weight/day, respectively. A reproductive and developmental NOAEL of 66 mg/kg-body weight/day was reported for mice and hamsters (IRIS 1995). IRIS reported a NOAEL of 507 mg/kg-body weight/day and a LOAEL of 1130 mg/kg-body weight/day for guinea pigs (IRIS 1995).

Selenium

Shepard's Catalog of Teratogenic Agents (Shepard 1995) reports that selenium is not teratogenic at maternally toxic levels.

Utah and Federal acute and chronic AWQC are 20 μg/l and 5 μg/l, respectively. ER-L and ER-M values for selenium are not reported by Long and Morgan (Long and Morgan 1990).

A toxic dose of 2 ppm was reported for goldfish (OHM-TADS 1995). LD50 values for rats range from 6 to 7600 mg/kg-body weight/day (OHM-TADS 1995, *Toxicology and Applied Pharmacology* 1971). Opresko reported a LOAEL value of 0.57 mg/kg-body weight for mice

(Opreskco 1993). Oral LD50 values of 4 and 2 mg/kg-body weight/day were reported for dogs and cattle, respectively.

Sodium

Sodium is not listed as teratogenic by TERIS or *Shepard's Catalog of Teratogenic Agents* (TERIS 1995 and Shepard 1995). AWQC, ER-L, and ER-M values are not reported for sodium (Federal and State AWQC documents, Long and Morgan 1990).

A NOAEL of 4720 mg/l was reported for stickleback (OHM-TADS 1995). Chronic toxicity limits of 1000 ppm for all animals and 2000 ppm for livestock were reported (OHM-TADS 1995). An intraperitoneal LD50 of 4 g/kg-body weight for rats was reported by Bovet and Bovet-Nitti (Bovet and Bovet-Nitti 1948).

Sulfate

No ecotoxicity data were available for sulfate.

Tin

Neither TERIS nor *Shepard's Catalog of Teratogenic Agents* (TERIS 1995 and Shepard 1995) lists tin as teratogenic. AWQC, ER-L, and ER-M values are not reported for tin (Long and Morgan 1990).

Ingestion of tin powder caused vomiting but not permanent injury in rats (International Labor Office 1983). Tin was tumorogenic when implanted at a rate of 395 mg/kg-body weight in rats (Research Communications in Chemical Pathology and Pharmacology 1977).

Vanadium

Vanadium poisoning in rats led to reduced food and water ingestion, hemorrhaging from the nose, diarrhea, weight loss, hind-limb paralysis, labored respiration, convulsions, and death. Vanadium adversely affects the adrenal cortex, brain, spinal cord, bone marrow, liver, kidney, and lung (Zaporowska and Wasilewski 1989, Gosselin et al. 1984). High concentrations (0.8 mg/mL water)of orally-administered vanadium led to hypoglycemia in animals (Meyervitch 1987).

Paternain report that vanadium is not teratogenic (Paternain et al 1987).

AWQC, ER-L, and ER-M values are not reported for vanadium (Long and Morgan 1990).

Hilton and Bettger reported that 0-10 g/kg of vanadium in food caused reduced growth in rainbow trout (Hilton and Bettger 1988). At 493 g/kg in food, rainbow trout demonstrated food avoidance and increased mortality. While a minimum toxicity level was not determined by the study, it probably is less than 10 mg/kg in food (Hilton and Bettger 1988).

A subcutaneous LD50 of 59 mg/kg-body weight was reported for rabbits (*Farmakologiya i Toxicologiya* 1965).

Zinc

Zinc is an essential trace metal; zinc-deficient rats showed dermatitis, emaciation, testicular atrophy, and retarded growth (Friberg et al. 1986). However, at high concentrations, zinc becomes toxic. Zinc poisoning results in lassitude, slow reflexes, diarrhea, lowered leukocyte count, depression of the central nervous system, and paralysis of extremities (Venugopal and Luckey 1978). Young animals tend to be more susceptible to zinc poisoning than mature animals (Clarke et al. 1981).

Zinc is not listed as teratogenic by TERIS or Shepherd's Catalog of Teratogenic Agents (TERIS 1995 and Shepard 1995).

Utah and Federal acute and chronic AWQC are 120 μg/L and 110 μg/L, respectively. Long and Morgan reported and ER-L of 120 ppm and an ER-M or 270 ppm in sediment (Long and Morgan 1990).

LC50 values for fish range from 0.67 ppm for a 14-day bioassay with cutthroat trout to 7.2 ppm for a 96-hour bioassay with rainbow trout (OHM-TADS 1995).

Opresko reported a LOAEL value of 1.7 mg/kg-body weight/day for mallard ducks (Opresko et al. 1993). Sutton and Nelson and Lewis reported a NOAEL value of 75 mg/kg-body weight/day for rats (Sutton and Nelson 1937 and Lewis et al. 1957).

Toxicity Benchmark Values

Calculated doses (for peregrine falcon, muskrat, mule deer, and deer mice) and measured concentrations (cliff swallows for southwest willow flycatcher and spotted bat, and benthic macroinvertebrates for aquatic prey species) will be compared to the NOAEL and the LOAEL for each COPC to obtain hazard quotients. The NOAEL and LOAEL were obtained for each contaminant by multiplying ecotoxicity values from the scientific literature by uncertainty factors. Uncertainty factors were applied if (1) the toxicity benchmark value was not a chronic NOAEL, (2) if the toxicity benchmark value was for a species other than the receptor of concern, or (3) if the exposure pathway was different from the pathway under consideration. If a chronic NOAEL was found in the scientific literature, the LOAEL was obtained by dividing the NOAEL by an uncertainty factor.

Table 4.5-37 presents the raw toxicity data, the uncertainty factors applied to the raw data, and the resulting LOAEL and NOAEL values for OU III metals COPCs.

Ecotoxicity data have not yet been identified for radionuclides and/or gross alpha, beta, and gamma radioactivity. EPA is currently reviewing wildlife-specific radionuclide toxicity benchmarks that have been developed for use in the Rocky Flats, Colorado, National Priorities

List (NPL) site. If these benchmarks are available, they will be used for the OU III risk assessment.

Histopathological Analyses

Histopathological results from samples collected in OU III will be compared to results from samples collected in the reference area to determine whether OU III cliff swallows have significantly higher rates of abnormalities.

4.5.5.3 Risk Description

In this step, hazard quotients will be calculated. For aquatic prey species and fish, the hazard quotient is the ratio of abiotic exposure point concentration (from abiotic analytical data and ground-water modeling data) to the Federal or State AWQC, or to concentration-based LOAEL and NOAEL values in µg/L. For the spotted bat and southwestern willow flycatcher, the hazard quotient is the ratio of the measured cliff swallow concentration to tissue-concentration toxicity benchmark values, in mg/kg. For the remaining receptors, the hazard quotient is the ratio of the calculated dose to LOAEL and NOAEL values, in mg/kg body weight/day. Hazard quotients that exceed 1.0 indicate a potential for ecological risk.

Hazard indices (sums of hazard quotients for groups of contaminant with similar toxicity mechanisms) will be calculated to estimate risk from receptors' exposure to multiple contaminants.

4.5.5.4 Uncertainty Analysis

A qualitative uncertainty analysis will be performed to address major sources of uncertainty in the risk assessment. Major sources of uncertainty include not only sampling and data uncertainty, but also uncertainty in the risk estimates due to uncertainty in the toxicity benchmark values, modeling estimates, and other information included in the risk equations.

4.5.5.5 Risk Summary

In the Risk Summary, two methods will be used to draw conclusions as to the hazard posed by COPCs at the site. These are the hazard quotient approach and the weight of evidence approach. Uncertainty in the data and the risk determinations also will be discussed.

The weight of evidence approach includes not only the quantitative risk calculations or hazard quotients, but also the ecological survey and other data collected from the site that are comparable to data collected from the reference area. If data collected from the site are significantly different from data collected from the reference area, and habitat and physical variables can be ruled out as the cause, the evidence suggests that the site is affecting the parameters under consideration. Because only one season of field data will be available, these data are not as strong as they could be if several seasons of data were available. However, together with the hazard quotients, the evidence is used to determine if adverse effects are likely to be occurring at the site due to elevated concentrations of source-related contaminants.

4.5.5.6 Interpretation of Ecological Significance

Interpretation of Ecological Significance will be conducted in accordance with EPA's *Framework for Ecological Risk Assessment* (EPA 1992a). The interpretation will place risk estimates in the context of the types and extent of anticipated effects. Aspects of ecological significance that may be considered include the nature and magnitude of the effects, the spatial and temporal patterns of the effects, and the potential for recovery once stressors are removed.

4.6 Task 5: Human Health Risk Assessment

The mandate of CERCLA and the NCP is to protect human health and the environment from current and potential threats posed by exposure to uncontrolled hazardous substance releases. To help achieve this mandate, EPA has developed a risk assessment process as part of its remedial investigations program under CERCLA. According to the *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual* (EPA 1989c), the goal of the risk assessment process is " ...to provide a framework for developing the risk information necessary to assist decision making at remedial sites." In other words, site-specific data are used to develop the risk assessment that is used to support risk management decisions. Specific objectives of a risk assessment are to provide:

- An analysis of baseline risks and to help determine the need for action at sites;
- A basis for determining levels of chemicals that can remain on site and still be protective of public health;
- A basis for comparing potential health impacts of various remedial alternatives; and
- A consistent process for evaluating and documenting potential human health threats at sites (EPA 1989c).

A baseline risk assessment that meets the objectives listed above will be developed for OU III at the MMTS. The human health component of the baseline risk assessment will be developed on the basis of the *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual* (EPA 1989c). This section describes the conceptual site model, the approach for the major components of the human health risk assessment, preliminary site calculations, data quality objectives, COPCs, sampling program, and analytical program.

Sections 4.6.1 through 4.6.3 address the preliminary activities that laid the groundwork for the juman risk assessment. Section 4.6.4 presents the proposed hu;man health risk assessment activities to be performed under the RI.

4.6.1 Conceptual Site Model

A Conceptual Site Model was developed with available data to provide a *preliminary* understanding of the sources of contamination, the migration pathways of contaminants, and

potential receptors that may contact contaminants within upper and lower Montezuma Creek. The CSM was also used to assess the adequacy of present information and to identify data gaps. The risk assessment information will be used in conjunction with the other CERCLA criteria to evaluate remedial alternatives. Figure 4.6-1 presents the preliminary conceptual site model for the human health risk assessment.

4.6.1.1 Primary Contaminant Source

Mill tailings in four piles in or near the Montezuma Creek stream channel at the millsite are the primary original source of contamination in upper and lower Montezuma Canyon. Through a variety of release mechanisms (discussed in Section 4.6.1.3), tailings and tailings-related contaminants have migrated from this source. The millsite tailings will be removed as part of OU I which will be remediated according to the 1990 ROD for OUs I and II.

4.6.1.2 Secondary Contaminant Sources

- **Sediments**

A secondary source of contamination along Montezuma Creek is contaminated sediments. These sediments may be either beneath the water surface in Montezuma Creek (i.e., in the creek bed) or above the water surface (e.g., in floodplain or former stream-channel deposits). The original source of the contaminated sediments along the creek is the mill tailings that have migrated downstream of the millsite via surface water/sediment transport or, potentially, the leaching and reabsorption of the contaminants. Recent gamma scan surveys (see Appendix B) indicate that contaminated sediments have potentially migrated to the downstream boundary of OU III, which is approximately 0.5 miles below the confluence of Montezuma Creek and Vega Creek.

- **Surface Water and Ground Water**

Other secondary sources of contamination in the canyon and on the millsite are contaminated surface water and contaminated ground water in the upper ground-water flow-system. The original source of the contamination of these two media is also tailings at the millsite.

4.6.1.3 Release Mechanisms

- **Surface Water Runoff**

Surface water flow in Montezuma Creek releases contaminants to media along the creek by transporting tailings materials from existing piles and soil beneath the piles and by scouring and redepositing indigenous and/or tailings-related sediment particles on which contaminants are adsorbed. The potential residual risks from leaching of contaminated soils and sediments into surface-water runoff will be evaluated in the human health risk assessment. Some low-level residual contamination below the 5/15 pCi/g standard will remain in the soil at the millsite after OU I is remediated according to the existing ROD.

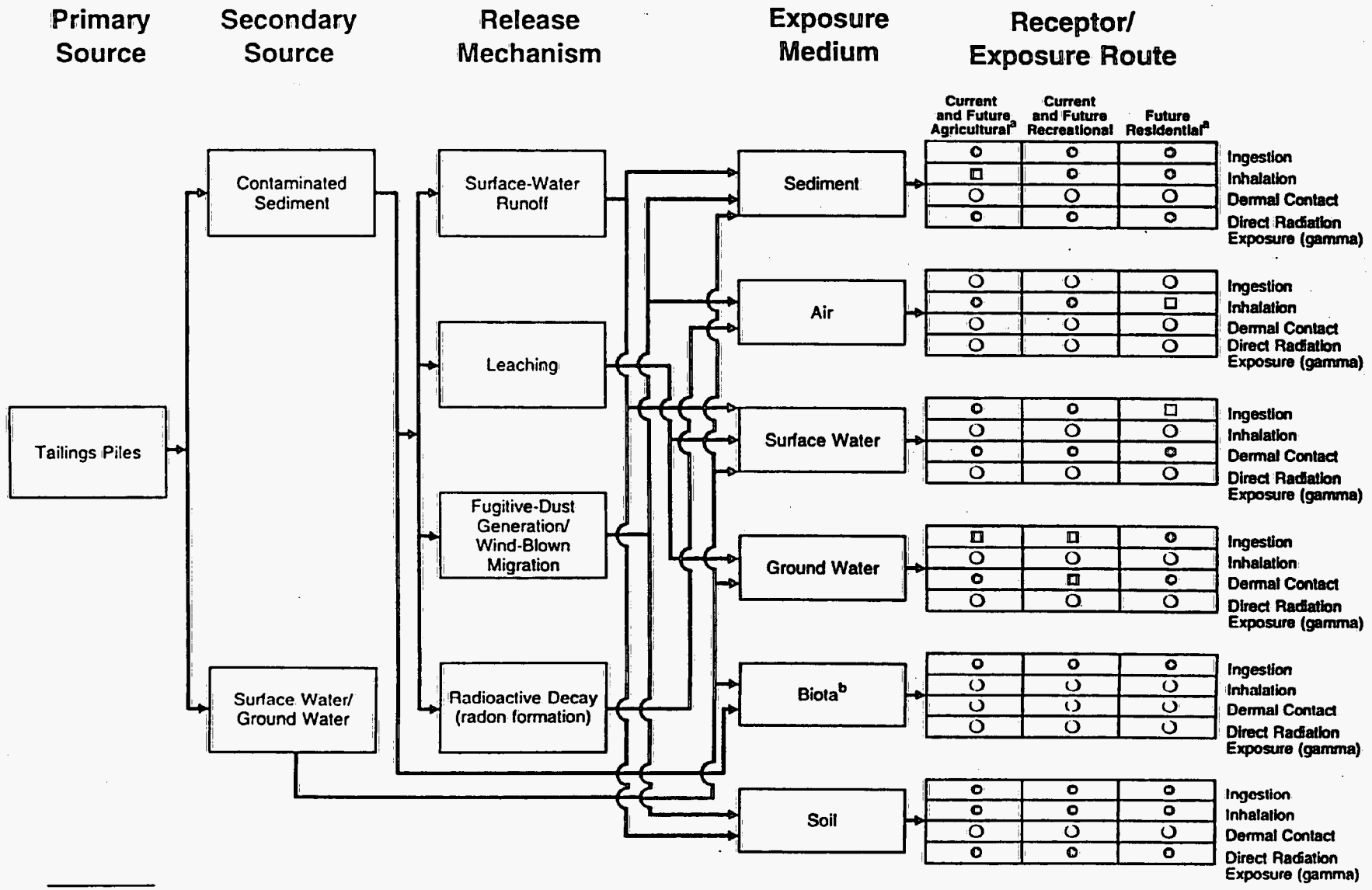


Figure 4.6-1. Conceptual Site Model for Human Health Risk Assessment

[a]Residential and agricultural land use is assumed to occur in the upper area of OU III above the narrow part of the canyon. After the canyon narrows, only recreational use is assumed.

[b]Includes terrestrial animals (e.g., cattle, deer), farm-grown crops, and garden vegtables.

- **Leaching to Surface Water and Ground Water**

Mill tailings materials, either at the millsite or deposited in the sediments along Montezuma Creek, may leach into the surface water or ground water. Similarly, contamination adsorbed onto indigenous sediments along the creek may leach into the surface water and ground water, and contamination in ground water may discharge from the upper ground-water flow-system to surface water. The potential residual risks from leaching of sediments along the creek and residual soils left on the millsite into surface water and ground water will be examined in the human health risk assessment.

- **Fugitive Dust Generation/Wind Blown Migration**

Wind may suspend tailings materials from the surface of the piles at the millsite and residual soil contamination after the piles are removed or may transport contaminated sediments along Montezuma Creek but above the water surface. Although the generation of fugitive dust from the contaminated sediments is probably negligible, the potential risks from inhalation of fugitive dust will be evaluated using the available air monitoring data collected for the MMTS.

- **Radioactive Decay**

Radon is produced from contaminated sediments along the creek during the radioactive decay process of Ra-226. Radon exposure to humans will be determined on the basis of 40 CFR 192 remedial action standards. In addition, gamma radiation will be evaluated.

4.6.1.4 Exposure Media

Contaminated media will be characterized by the activities detailed in this Work Plan so that human exposure by ingestion, inhalation, dermal contact, and/or direct radiation exposure can be evaluated.

- **Sediment**

Contaminants may be present at hazardous levels under existing or certain future land use scenarios in the sediments from deposition of tailings materials, adsorption onto indigenous sediment, or because of contaminated pore water.

- **Surface Water**

Contaminants may be present at hazardous levels under existing or some potential future land use scenarios in Montezuma Creek surface water at and downstream of the millsite as a result of surface-water transport of contaminants leached from the tailings piles or residual contamination in soils, discharge of contaminated ground water from the upper ground-water flow-system, and leaching from transported tailings materials, residual contaminated soils, or indigenous sediments on which contaminants have adsorbed.

- **Ground Water**

Contaminants may be present at hazardous levels under existing or some potential future land use scenarios in the ground water at the millsite and downgradient of the millsite as a result of ground-water transport of contaminants leached from the tailings piles or residual contamination in soils and by leaching from transported tailings materials or indigenous sediments on which contaminants have adsorbed. Ground water beneath Montezuma Creek also may be contaminated by the seepage of contaminated surface water (e.g., at the beaver dams) or by the leaching of alluvial sediments from the surface-water flow.

- **Air**

Wind-suspended tailings materials from the surface of the piles at the millsite, residual contamination in soils, or contaminated sediments may reside in the breathing zone of the air column, or settle directly on the surface of plants or on the ground surface. In addition, the presence of Ra-226 in the tailings materials indicate that radon and radon daughters may be produced by radioactive decay and migrate into the air column at levels potentially above background.

- **Biota**

Humans could be exposed to contaminants through biota. Biota of potential concern to humans are farm livestock (e.g., beef and dairy cattle), game animals, and farm-grown crops and garden vegetables (exposed to contaminated water and soil).

- **Soil**

Contaminants may be present in the soil because of wind blown migration of contaminants from the tailings piles or flood-deposition of contaminated sediments. Soils could also become contaminated from the leaching of contaminants from the tailing piles into soils.

4.6.1.5 Human Receptors

Children and adults will be considered as potential receptors for the human health risk assessment. The magnitude of their exposures will be greatly dependent upon the various land uses and exposure routes evaluated.

- **Land Use**

Three potential land uses will be considered for the upper and lower Montezuma Creek and millsite. Both current and future recreational use is assumed and includes activities such as hiking, camping, and hunting. Agricultural use will be assumed for both current and future scenarios. Surface water from Montezuma Creek is used for irrigation and this use is anticipated to continue into the future. Currently, there are no residences on top of or directly adjacent to contaminated soils included in OU III. Future residences are possible in the

canyon, although they are not considered likely because of floodplain considerations, wetlands, and the anticipated magnitude and direction of growth of Monticello. The final future land-use assumptions, however, have not been determined by the remedial project managers. Until this decision is made, it will be assumed for the purpose of the Work Plan that some future residential land use will occur in upper Montezuma Creek. The portion of the study area referred to as upper Montezuma Creek extends east from U.S. Highway 191 to the point at which the canyon narrows (see Figure 1.0-3). Lower Montezuma Creek will be considered as recreational in the future land-use scenario and agricultural (cattle grazing only) for both the current and future land use scenarios.

- **Exposure Routes**

The exposure-route/exposure-medium combination listed below will be considered for the following receptors:

Agriculture (Rancher/Farmer)

- Ingestion of sediment, surface water, biota, soil, and potentially ground water.
- Inhalation of air (fugitive dust and radon).
- Dermal contact with surface water, and ground water.
- Direct radiation exposure (gamma exposure) to radiological contaminants from sediments and soil.

Recreational (Hiker and Hunter)

- Ingestion of sediment, surface water, biota, soil, and potentially ground water.
- Inhalation of air (fugitive dust and radon).
- Dermal contact with surface water.
- Direct radiation exposure (gamma exposure) to radiological contaminants from sediments and soils.

Residential (Children and Adults)

- Ingestion of sediment, ground water, biota, soil, and potentially surface water.
- Inhalation of air (fugitive dust and radon).
- Dermal contact with surface water and ground water.

- Direct radiation exposure (gamma exposure) to radiological contaminants from sediments and soils.

4.6.2 Components of the Human Health Risk Assessment

The major components of a baseline human health risk assessment are:

- Data collection/data evaluation
- Exposure assessment
- Toxicity assessment
- Risk characterization

4.6.2.1 Data Collection/Data Evaluation

This Work Plan describes the major activities for the data-collection phase of the human-health risk assessment. The most important aspects of the activities described in this Work Plan that will be used to support the risk assessment are (1) review/use of available site information, (2) definition of background sampling needs, (3) incorporation of the conceptual site model into the sampling strategy, and (4) consideration of the modeling parameter needed to estimate future residential exposures.

An initial review of the available site data has been completed. On the basis of this review, it appears that some exposure pathways are complete for all six exposure media. A review of the existing data also indicates that limited additional information is needed to evaluate potential risks according to the *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual* (EPA 1989c) and *Guidance for Data Useability in Risk Assessment* (EPA 1992b).

- The concentration and distribution of contaminants in sediments are poorly understood, particularly for metals. This information is needed to estimate risks to current and future receptors and will be gathered as part of the ecological risk assessment (see Section 4.5).

- Adequate data exist to evaluate exposure to contaminants in air for the current scenario. Modeling may be required to assess future exposure to contaminants in air. Modeling will not be necessary if the current scenario risk is not important and conditions are not assumed to change significantly.

- Surface water is currently not used as a drinking water source nor is it anticipated to be used as a drinking water source in the future because of the availability of potable ground water and/or city-supplied drinking water. However, according to the State classification for Montezuma Creek, this water could be used for drinking water after treatment.

Surface water also serves as an important contamination source to biota (crops, cattle) that will be ingested by humans. Some surface water data are available, and additional data will be gathered as part of the annual monitoring program.

- The Burro Canyon aquifer could be used as a source of drinking water. It is currently not contaminated but may become contaminated in the future. Ground water could be used to irrigate crops or as a drinking water source, assuming a future residential land-use scenario. Additional wells will be added to the Burro Canyon aquifer monitoring network to supplement the existing network. The wells will be monitored quarterly for the first year and then incorporated into to annual monitoring program.

- Human consumption of deer and cattle, farm-grown crops, and garden vegetables is likely. Continued agricultural use of the canyon is considered very likely and ingestion of biota could be an important pathway. Additional information may be needed to estimate risks associated with the ingestion of cattle, farm-grown crops, and garden vegetables. Both cattle and deer will be both exposed to contaminants from grazing and the ingestion of surface water.

- The upper ground-water flow system has been used near the site. Continued use of this system is expected. Other than the annual monitoring program, no additional data will be gathered from the upper ground-water flow system to support the human health risk assessment. Ground-water modeling will be used to assess future contaminant concentrations in the upper ground-water flow system.

- Soil includes the areas within OU III above the sediment deposits. Soil may serve as an important exposure medium for all of the evaluated exposure scenarios, particularly assumed future residential use in upper Montezuma Canyon.

Once all the data are available, the major steps during the data evaluation process will be to (1) combine data from multiple sources, (2) evaluate analytical methods, quantitation limits, and qualified data, (3) compare concentrations detected in blanks with concentrations detected in samples, and (4) compare analytical results of samples with background levels. On the basis of the analytical results, further reduction of the number of COPCs will be done as part of the risk assessment.

4.6.2.2 Exposure Assessment

The objective of an exposure assessment is to estimate the type and magnitude of exposure to the COPCs that are present or released from a site. The results of the exposure assessment are combined with the chemical-specific toxicity information to characterize potential risks (EPA 1989c).

The three major parts of an exposure assessment are (1) characterization of the exposure setting (physical characteristics of OU III and the adjacent populations), (2) identification of exposure pathways (this will involve refinement of the conceptual site model), and

(3) quantification of exposure (quantification of the magnitude, frequency, and duration for each identified pathway). Exposure parameters will be obtained from the *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (EPA 1991) or the *Exposure Factors Handbook* (EPA 1989a).

Several issues associated with the exposure assessment will require approval by the RPM and the State before proceeding (EPA 1989b):

- Determination of potential future land use
- Exclusion of exposure pathways from quantitative analysis
- Evaluation of chemical transport in sediment and ground water

4.6.2.3 Toxicity Assessment

The purpose of the toxicity assessment is to evaluate information concerning the potential for contaminants to adversely affect exposed individuals and, where possible, to estimate the relationship between the extent of exposure to a contaminant and the increased likelihood and severity of adverse effects (EPA 1989c).

The primary source for toxicological data will be EPA's *Integrated Risk Information System* (IRIS). The secondary source will be the *Health Effects Assessment Summary Tables* (HEAST) (EPA 1993c).

The toxicity assessment will include brief toxicological profiles on the COPCs and a discussion of the uncertainties. Separate tables will identify potential carcinogenic and noncarcinogenic effects.

4.6.2.4 Risk Characterization

Risk characterization integrates the exposure and toxicity assessments into quantitative and qualitative expressions of potential risk. The major steps that will be followed during the risk characterization are to (1) organize outputs of the exposure and toxicity assessments, (2) quantify pathway risks (total cancer risk and noncancer hazard index), (3) combine risks across pathways that affect the same individuals over the same time periods, (4) evaluate uncertainties, and (5) summarize results of the baseline risk assessment (EPA 1989c).

4.6.3 Preliminary Site Calculations

This section presents a preliminary screening assessment of potential human health risk and surface water and ground water regulatory status conditions at OU III based on prior information. The objective of the screening assessment is to identify those media (e.g., ground water), contaminants, and pathways that are of greatest risk or regulatory concern so that the study design can be focused to identify a risk assessment decision scenario, and specify

the data necessary for those decisions. The screening assessment does not supplant an integrated multimedia baseline risk assessment (BRA). It employs conservative single medium, single pathway concentration benchmark indices for ease of comparison. The benchmarks are not preliminary remediation goals (PRGs) because they address only a single pathway.

4.6.3.1 Preliminary Benchmark Calculations

The preliminary calculations developed herein designate a set of chemical and media benchmark concentrations in ground water, surface water, sediment, and soil that are significant from a human health risk screening perspective. They are intended for two purposes:

1. Facilitate an appraisal of specific media in terms of potential human health risk by comparing measured concentrations with the benchmarks.

2. Evaluate analytical sensitivities to support identifying methods for the chemical analysis program.

Table 4.6-1 lists the major exposure parameters used for the benchmark computations. Using the exposure assumptions from Table 4.6-1 and current EPA toxicological dose response factors, preliminary human health screening benchmarks were developed for known or suspected carcinogenic substances (Table 4.6-2) and for compounds presenting known or suspected adverse noncarcinogenic effects (Table 4.6-3). Toxicological factors including cancer slope factors for potentially carcinogenic compounds and reference doses (RfD's) for systemic toxicants were obtained from EPA's IRIS data base. The factors and other computational details are identified in Appendix D. These benchmarks represent the media-specific concentrations that, in theory if administered according to the assumptions in Table 4.6-1, would result in a computed lifetime excess cancer risk of 1E–6 to 1E–4 or an average daily intake equal to the reference dose, thereby giving a hazard quotient (HQ) of 1.0.

Table 4.6-1. Main Exposure Parameters Used for Preliminary Human Health Benchmarks

Input Parameter	Residential	Recreational
Exposure duration	30 years	30 years
Frequency	350 days/year	7 days/year
Water ingestion	2 liters/day	0.13 liter/day
Soil ingestion	114 mg/day	A
Sediment ingestion	A	2.7 mg/day
Averaging time (carcinogens)	70 years	70 years
Averaging time (noncarcinogens)	30 years	30 years

A = For screening purposes, each media is considered separately and exposure scenarios are not linked (e.g., soil and sediment ingestion).
Preliminary benchmark exposure parameters are conservative and generally consistent with EPA Guidance (e.g., EPA 1989d, EPA 1992b) for the purposes of screening and analytical detection limit estimation. The parameters in this table are generally upper bounding values and are not intended to comprise an RME scenario. Other parameters reflecting site specific conditions may be used in the Baseline Risk Assessment. Computation details can be found in Appendix D.

Table 4.6-2. Preliminary Human Health Screening Benchmarks
Potentially Carcinogenic Chemicals

Chemical	Ground Water (mg/l)	Surface Water (mg/l)	Soil (mg/kg)	Sediment (mg/kg)
Arsenic	5E-5	0.04	0.37	891
Beryllium	2E-5	0.02	0.15	363
Radionuclide	**Ground Water (pCi/l)**	**Surface Water (pCi/l)**	**Soil (pCi/g)**	**Sediment (pCi/g)**
Lead -210+D	0.07	56	1.20	237.06
Polonium -210	0.32	244	5.27	1278.78
Radium-226+D	0.40	305	0.01	0.01
Radium-228+D	0.48	366	0.01	0.01
Radon-222+D	28.01	21,574	0.01	0.01
Thorium-230	3.66	2818	56.57	767.19
Thorium-232	3.97	3053	63.52	1585.09
Uranium-234	2.98	2289	47.89	1371.42
Uranium-235+D	2.98	2289	0.17	0.17
Uranium-238+D	2.38	1832	0.80	0.82

mg/kg = Milligrams per kilogram; mg/l = Milligrams per liter; pCi/g = picoCuries per gram;
pCi/l = picoCuries per liter

Note: Preliminary benchmarks are arbitrarily set at a 1E-6 excess cancer risk for a single compound and a single ingestion pathway. The acceptable risk, r, range spans a factor of 100, from 1E-6 to 1E-4. Multiplying a benchmark in the table by 100 gives the corresponding 1E-4 excess risk concentration benchmark.
Example - Arsenic in ground water: 1E-6 benchmark is 5E-5 mg/l
5E-5 mg/l x 100 - 5E-3 (i.e., 5 μg/l)

Table 4.6-3. Preliminary Human Health Screening Benchmarks
Potential Systemic Noncarcinogenic Effects

Compound	Ground Water (mg/l)	Surface Water (mg/l)	Soil (mg/kg)	Sediment (mg/kg)
Aluminum	(A)	(A)	(A)	(A)
Antimony	0.01	11	110	267,400
Arsenic	0.001	1	8	20,055
Barium	2.56	1,965	19,211	46,794,872
Beryllium	0.18	140	1372	3,342,491
Cadmium	0.02	14	274	668,498
Chromium	0.18	140	1,372	3,342,491
Cobalt	(A)	(A)	(A)	(A)

Table 4.6-3. Preliminary Human Health Screening Benchmarks
Potential Systemic Noncarcinogenic Effects (Continued)

Compound	Ground Water (mg/l)	Surface Water (mg/l)	Soil (mg/kg)	Sediment (mg/kg)
Copper	1.35	1,039	10,154	24,734,432
Lead[b]	0.1	20	1800	3,253,740
Manganese	0.18	3,931	38,421	93,589,744
Mercury	0.01	8	82	200,549
Nickel	0.73	562	5,489	13,369,963
Selenium	0.18	140	1,372	3,342,491
Silver	0.18	140	1,372	3,342,491
Thallium	0.003	2	22	53,480
Vanadium	0.26	197	1,921	4,679,487
Zinc	10.95	8,423	82,331	200,549,451

mg/kg = Milligrams per kilogram; mg/l = Milligrams per liter; μg = Microgram; RfD = Reference dose
(A) = RfD not published
[b] Estimated using the IEUBK Lead Model (EPA 1994b) for a 10 μg/deciliter blood. See Appendix D.
Some potentially carcinogenic compounds in Table 4.6.2 also have associated systemic noncarcinogenic adverse health effects. The more conservative benchmark originates from the carcinogenic considerations. The corresponding systemic noncarcinogenic benchmark was not computed. Using the more conservative benchmark errs on the side of safety in the screening applications.

4.6.3.2 Initial Screening of Preliminary Health Risk and Regulatory Compliance

This section combines the preliminary benchmarks developed in Section 4.6.3 with summary monitoring data for the OU III study area and contrasts site specific concentrations with human health risk benchmarks and pertinent regulatory markers.

Maximum and average concentration data were used for this initial screening step, although 95 percent UCLs will be used in the BRA as more data become available.

Upper Flow System

The upper flow system, as indicated in the conceptual site model (Figure 4.6-1) is a central component of the human health risk assessment. This is because, although not currently so used, it is conceivable that ground water from this system could be used for domestic supply, and this ground-water system is a source of baseflow for Montezuma Creek.

Presented in Table 4.6-4 are pertinent regulatory and human health risk benchmarks for the upper ground-water flow system and a summary of recent upper flow system monitoring results for upgradient, millsite proper, and downgradient monitoring wells. Upgradient data are provided to promote an integrated view of the upper flow system in context of the site

conceptual model. Contrasting benchmarks with the monitoring data and noting exceedances (shaded boxes) indicate segments of the upper flow system of potential human health risk or regulatory concern. If a maximum concentration exceeds a benchmark, a localized condition is often indicated because some ground-water monitoring wells, such as those on millsite, are often located in a biased manner to identify source areas and maximum contaminant concentrations. Biased in this manner, they often identify localized contamination hot spots that are not reflective of overall contamination in the ground-water system. Ground-water extraction occurs over a spatial domain encompassing the overall of the system. When an average ground-water concentration exceeds a benchmark, the situation is normally more widespread and is often indicative of a greater potential health or regulatory issue.

Inspection of Table 4.6-4 indicates that chemical concentrations for several compounds in the upper flow system, downgradient of the millsite, exceed some benchmark values. Pertinent preliminary observations include:

1. On the millsite, upper flow system *maximum* concentrations of antimony, arsenic, lead, selenium, elemental uranium, vanadium, Ra-226, U-234, U-235, U-238, gross alpha and gross beta exceed the 1E-6 excess risk benchmark or a regulatory measure. Arsenic, U-234, and U-238 exceed their respective 1E-4 excess risk benchmarks. Antimony's exceedance of the 1E-6 excess risk benchmark occurred only once; this occurrence was at well 365E93-201-2, a well completed with backfill material in the northwest area at the millsite in the vanadium roast area. Turbidity of the sample was greater than 1000 NTUs.

2. On the millsite, upper flow system *average* concentrations of arsenic, elemental uranium, vanadium, U-234, U-235, U-238, gross alpha and gross beta exceed the 1E-6 excess risk benchmark or a regulatory measure. Concentrations of arsenic, U-234, and U-238 exceed 1E-4 excess risk benchmarks.

3. Within the downgradient upper flow system, *maximum* concentrations of arsenic, beryllium, chromium, lead, nickel, selenium, elemental uranium, vanadium, Ra-226, U-234, U-235, U-238, gross alpha and gross beta exceed the 1E-6 excess risk benchmark or a regulatory measure. Arsenic, beryllium, U-234, and U-238 exceed their respective 1E-4 excess risk benchmarks.

4. Downgradient upper flow system *average* concentrations of arsenic, beryllium, elemental uranium, vanadium, U-234, U-238, gross alpha and gross beta exceed the 1E-6 excess risk benchmark or a regulatory measure. Only arsenic exceeds its 1E-4 excess risk benchmark.

5. The sequence of upgradient-millsite-downgradient concentration profiles for elemental arsenic, selenium, elemental uranium, vanadium, Ra-226, U-234, U-238, gross alpha and gross beta suggest a source to receptor relationship consistent with the conceptual site model. Inspection of the data summary statistics (Annex C-1 of Appendix C) suggests that concentration ranges in the upper flow system do not vary widely over time, which

is consistent with a constant source magnitude and release term (e.g., the tailings) identified in the conceptual site model.

6. Upgradient arsenic and beryllium concentrations exceed 1E–6 excess risk benchmarks. It is not uncommon for ground-water arsenic and beryllium concentrations to exceed 1E–6 risk benchmarks, and occasionally regulatory thresholds owing to natural levels and conservative assumptions embodied in the computations.

This evaluation is intended to be indicative, not exhaustive; however, the major points identified above are consistent with site history and the conceptual site model. The data on which these findings are based reflect conditions resulting from the mill tailings (e.g., OU I) serving as a source to the upper flow system. The upper flow system ground-water quality will improve following remediation of OU I, although the time period required to protect human health will be estimated based on the results from the ground-water modeling.

Summary

In summary, this screening indicates:

1. In consideration of a hypothetical domestic future use of the upper flow system ground water, on the MMTS, and down gradient of the millsite, that there is an appreciable potential adverse health risk. This is because maximum concentrations of arsenic, beryllium, U-234, and U-238 exceed their respective 1E–4 excess risk benchmarks. When average concentrations are considered, only arsenic exceeds the 1E–4 excess risk benchmark. Contaminant concentrations tend to be higher for the MMTS than for the off-site areas to the east.

2. This assessment indicates some concern for regulatory compliance. Millsite and down-gradient upperflow system maximum concentrations of: arsenic, beryllium, chromium, lead, nickel, selenium, elemental uranium, vanadium, Ra-226, U-234, U-235, U-238, gross alpha and gross beta exceed regulatory markers (Table 4.6-4). Compounds whose average concentrations exceed regulatory measures include arsenic, elemental uranium, gross alpha and gross beta.

Montezuma Creek Surface Water System

Montezuma Creek, as indicated in the conceptual site model (Figure 4.6-1), receives significant baseflow from the upper flow system as well as runoff from the local watershed. From a human health risk perspective, and on the basis of observed activities, Montezuma Creek could serve as a point of exposure from recreational use and this is the principal pathway of concern. Montezuma Creek is also being used for agricultural purposes (i.e., watering cattle).

Table 4.6-5 contains pertinent regulatory and human health risk benchmarks for Montezuma Creek as well as a summary of recent monitoring results. As was described in the previous

section, monitoring results from sampling stations upgradient of the millsite, the millsite proper (which includes surface seeps), and downgradient are presented. Upgradient data are included to encourage a view of Montezuma Creek in context of the conceptual site model. Analogous to the previous discussion, contrasting benchmarks with the monitoring data and noting exceedances (shaded boxes) indicates whether specific reaches of the creek pose potential human health risk or regulatory concerns. When a maximum concentration exceeds a benchmark, a localized expression such as a seep or discharge may be the source. Average stream reach concentration exceedances often imply a greater potential health or regulatory issue.

Chemical concentrations for several compounds in Montezuma Creek exceed certain benchmark values as indicated in Table 4.6-5. Overall, Table 4.6-5 exhibits many "nondetect" reports and much lower concentrations than observed in the upper flow ground-water system. Pertinent preliminary observations include:

1. In the surface water reach on the millsite (i.e., MMTS), *maximum* concentrations of arsenic, selenium, elemental uranium, Ra-226, gross alpha, and gross beta exceed 1E-6 risk or regulatory benchmarks. No concentrations exceed 1E-4 risk benchmarks.

2. *Average* surface water concentrations on the millsite of arsenic, selenium, elemental uranium, gross alpha and gross beta exceed regulatory benchmarks. Arsenic is the only compound whose average reported concentration exceeds a 1E-6 risk benchmark. The average arsenic concentration (139.6 μg/l), however, is considerably less than the 1E-4 marker (3,700 μg/l).

3. Within the downgradient Montezuma Creek reach, *maximum* concentrations of elemental uranium, gross alpha, and gross beta exceed regulatory benchmarks. The average concentrations of elemental uranium and gross alpha also exceed regulatory benchmark values. No potential human carcinogens exhibit concentrations exceeding 1E-6 excess risk benchmarks and there are no compounds that exceed their systemic noncarcinogenic effect marker values.

4. *Average* Montezuma Creek concentrations downgradient of the millsite exceeding regulatory benchmarks include elemental uranium, gross alpha and gross beta.

5. In the upgradient reach maximum concentrations of elemental uranium and gross alpha exceed regulatory measures. The average upgradient gross alpha concentration (20.2 pCi/l) just exceeds the 15 pCi/l regulatory benchmark.

6. The upgradient-millsite-downgradient Montezuma Creek concentration patterns for elemental arsenic, selenium, elemental uranium, vanadium, Ra-226, U-234, U-235, U-238, and gross alpha and gross beta suggest a source to receptor relationship consistent with the conceptual site model.

These screening level findings are consistent with the site history and the conceptual site model. The data on which these findings are based reflect conditions resulting from the mill tailings (e.g., OU I) serving as a source to surface water. It is expected that following remediation of OU I, Montezuma Creek water quality will improve substantially.

Summary

In summary, this screening indicates that:

1. Recreational use of surface waters in the reach on the MMTS and in Montezuma Creek below the site results in a low estimate of potential adverse health risk. This is because only one compound considered a potential human carcinogen (arsenic) exhibits concentrations exceeding the 1E-6 excess risk benchmark, and there are no compounds with concentrations that exceed systemic noncarcinogenic effect marker values.

2. Maximum and average concentrations of arsenic, selenium, elemental uranium, Ra-226, gross alpha, and gross beta exceed regulatory benchmarks. This indicates some concern for regulatory compliance.

Sediment/Soil Along Montezuma Creek

According to the site conceptual model (Figure 4.6-1), surface and subsurface sediment/soil along Montezuma Creek have the potential to serve as a source for exposure to humans. Subsurface materials have the potential to become surface materials because of the active fluvial system and the effects of scouring. On the basis of observation and as discussed in Section 4.6.1, recreational use is the current and future maximum exposure scenario for lower Montezuma Creek.

Presented in Table 4.6-6 are preliminary human health benchmark concentrations and a summary of recent sediment/soil sampling and analysis reports for the top 6-inch sediment/soil horizon (Note that the top 6 inches is being used as part of the initial analysis, additional data will be gathered for the top 2 inches, based on a recommendation of the ETAG). Comparing preliminary benchmarks with the soil data gives an indication of potential human health concern. As discussed in previous sections, if a maximum or 95 percent UCL concentrations exceed a benchmark, a localized condition is often indicated. When an average sediment/soil concentrations exceed a benchmark, a more widespread condition is often indicated.

Table 4.6-6. Comparison of Sediment/Soil Samples Collected from 0 to 6 Inches Below Ground Surface and Preliminary Benchmarks

Constituent	Benchmark[a] mg/kg	Mean mg/kg	95% UCL mg/kg	Maximum mg/kg
Aluminum	-	8503.1	11511.8	21923.2
Antimony	110.0	nondetect	nondetect	nondetect
Arsenic	0.37 to 37	7.4	13.6	12.7
Barium	19211.0	169.1	245.7	260.0
Beryllium	0.15 to 15	0.5	0.7	0.7
Cadmium	274.0	0.2	0.6	0.8
Chromium	1372.0	7.0	9.6	9.8
Cobalt	-	5.9	8.5	9.6
Copper	10154.0	58.0	166.6	193.0
Iron	-	11331.3	14898.2	15000.0
Lead	1800	13.0	19.8	22.5
Manganese	38421.0	383.1	472.6	490.0
Mercury	82.0	0.02	0.03	0.03
Molybdenum	-	1.6	2.8	2.8
Nickel	5489.0	10.8	13.1	12.6
Selenium	1372.0	0.6	1.6	1.6
Silver	1372.0	0.1	0.3	0.4
Thallium	22.0	0.2	0.5	0.6
Tin	-	nondetect	nondetect	nondetect
Uranium	-	16.4	41.3	26.5
Vanadium	1921.0	105.7	341.2	488.0
Zinc	82331.0	50.5	68.5	66.4
K-40		15.46	25.37	20.2
Ra-226	0.01 to 1.0	17.91	61.38	74.2
Th-232	63.52 to 6352	1.77	4.38	4.0

[a] Benchmarks based on 1E-6 to 1E-4 risk range and HQ = 1.0 in a recreational scenario.
Shaded values indicate an exceedance of the regulatory or risk-based benchmark.
See Appendix C for more detailed explanation.

Inspection of Table 4.6-6 indicates that

1. Average, 95 percent UCL, and maximum concentrations exceed benchmarks for arsenic, beryllium, and Ra-226.

2. No other benchmark exceedances are noted.

Arsenic, beryllium, and Ra-226 occur naturally in the environment. Table 4.6-7 presents typical ranges of these constituents as they occur in nature. Comparing the measured concentrations reported in Table 4.6-6 with corresponding values in Table 4.6-7 suggest that both arsenic and beryllium are likely to be natural, but may be slightly elevated above background, while Ra-226 is definitely elevated above background. These observations are consistent with the details presented in Appendix C. However, it should be noted that the analysis presented in Appendix C results in more COPCs than illustrated here, because the Appendix C analysis, which is based on EPA guidance, assumed a more conservative approach and was more rigorous and comprehensive than the discussion in this section.

Table 4.6-7. Typical Natural Background Concentrations of Arsenic, Beryllium, and Radium-226 in Sediment/Soil

Constituent	Typical Sediment/Soil Concentration	Remarks/References
Arsenic	1.7 to 27 mg/kg	Loamy/Clay[a]
Beryllium	0.04 to 2.54 mg/kg	U.S. Soils[a]
Radium-226	0.42 to 1.3 pCi/g	Various[b]

[a] Kabata Pendias 1992
[b] Eisenbud 1987
See Appendix C for more detailed comparison to background for these constituents.

Summary

On the basis of these assessments, it appears that Ra-226 concentrations, and possibly arsenic and beryllium concentrations, in sediment/soil along Montezuma Creek are elevated with respect to typical background concentrations. Ra-226 concentrations correspond to an added cancer risk greater than 1E-4. Data were also collected for deeper sediment/soil (i.e., greater than six inches below ground surface). Although some variations between the two data are apparent, overall the data are comparable and reflect similar health risk profiles.

Air

This section presents an assessment, based on preliminary computations, of the potential impacts associated with airborne contaminants in the vicinity of the MMTS. This information will be used to gauge the potential for human health impacts anticipated in OU III. This will be completed by assuming that any air pathway related risks in OU III would be less than those observed at and around the millsite. This assumption is justifiable in air, and resultant reduced concentration, with increasing distance from a source.

Table 4.6-8 presents a summary of estimated lifetime excess cancer risks, and EDEs computed using historical air quality measurements from the millsite ambient air monitoring system. The controlling comparison criterion applicable for this information are:

1. The EPA risk range of 1E-4 to 1E-6 cited in the National Contingency Plan (NCP) (40 CFR Part 300).

2. The 100 mrem/year dose limitation recommendation from the National Council on Radiation Protection (NCRP) (NCRP 1971).

3. The natural and unavoidable radiation dose of 100 to 350 mrem/year (National Academy of Sciences [NAS] 1990).

Table 4.6-8. Preliminary Risk and Effective Dose Equivalent Estimates from the Historical Air Measurements.

Data Group	30-Year Risk (average)	30-Year Risk (95% UCL)	Annual EDE mrem/year (average)	Annual EDE mrem/year (95% UCL)
Station 7 (background)	1E-5	7E-5	0.29	1.24
Stations 1-6 (MMTS perimeter)	5E-6	1E-5	0.21	0.46
Stations 1-5 (select perimeter)	5E-6	1E-5	0.21	0.47
Station 6 (SW of millsite)	7E-6	6E-6	0.21	0.34

Analytes include Ra-226, Th-230, and total uranium (taken as U-238).
Average is based on the average radionulcide concentration.
95% UCL is based on the upper 95 percent confidence limit estimate of the average radionuclide concentration.
Assumptions:
- 365 days/year exposure
- 20 cubic meters of air inhaled daily
- 30 years continuous exposure (cancer risk)
- Cancer slope factors from IRIS
- Radionuclide dose conversion factors from Federal Guidance Report No. 11

As evidenced, all average and 95 percent UCL cancer risk estimates are within the EPA's acceptable range. One 95 percent UCL estimate (7E-5 from the background station, which is five miles north of the millsite) is within the upper one-third of the range. Additionally, all EDE estimates are far below the NCRP's recommended dose limit of 100 mrem/year. Estimated EDEs, when compared to the natural radiation dose, suggest millsite-related doses cannot be differentiated from background.

The monitoring stations were segregated in Table 4.6-8 to promote observance of spatial differentiation dose owing to patterns of wind dispersion. Although some variation is evident, there is no apparent significant irregularity in the data. In fact, the numerically computed highest risk is actually associated with the background sampler. However, this observance is more related to a computation artifact than measurement conclusion. In total, the air data base contained numerous nondetect (i.e., below detection limit) reports. When data are heavily censored by nondetect reports, computational artifacts resulting from substitution of one-half detection limit values are common. The lowest estimated risks and doses are associated with Station six, located immediately southwest of the millsite.

Summary

The computations discussed above indicate that the air pathway is not a significant contributor to OU III human health hazards. This assessment further indicates that no further air concentration data will be required to address the potential human health risks associated with OU III.

4.6.4 Study Design

This subsection contains information on the data quality objectives, preliminary contaminants or concern, assessment program, and analytical program.

4.6.4.1 Data Quality Objectives

The general steps of the DQO process described in Section 4.1 were implemented to identify specific data needs for the human health risk assessment. Relevant steps of the DQO process as it applies to the human health risk assessment are discussed in this work plan as follows:

Step 1 (State the Problem). The ETAG committee members involved in the DQO scoping for the OU III RI, including the human health risk assessment, are the same as those listed in Section 4.5.4.1.

Problem statements or objectives for the human health risk assessment are the result of meetings and consensus between ETAG committee members. The conceptual site model for the human health risk assessment, presented in Section 4.6.1, identifies exposure media for which human exposure pathways may be complete. For each exposure medium evaluated in the human health risk assessment, one or more specific objectives are identified on Tables 4.6-9, 4.6-10, 4.6-11, 4.6-12, and 4.6-13. These objectives are the basis for establishing data needs.

Step 2 (Identify the Decision). Decisions to be made based on the data obtained are depicted as questions under the Decision heading on Tables 4.6-9, 4.6-10, 4.6-11, 4.6-12 and 4.6-13. In addition, decision flow diagrams were developed for the upper ground-water flow system

(Figures 4.6-2 and 4.6-3); surface water and sediment of Montezuma Creek (Figures 4.6-4 and 4.6-5); soil of Montezuma Canyon (Figures 4.6-6 and 4.6-7); and biota represented by cattle that graze in Montezuma Canyon (Figures 4.6-8 and 4.6-9).

Figure 4.6-2 illustrates the conceptual risk assessment decision scenario for the upper ground-water flow system. Evaluation of hypothetical future conditions in this framework can lead to a decision of acceptable or unacceptable human health risk. As indicated, the figure identifies those conditions necessary for a deduction of unacceptable risk. Two variables must both be present spatially and temporally in order for an unacceptable risk to be reasoned; thus:

1. There must be human exposure in accordance with the assumptions of the exposure scenario (conservatively assumed to be domestic use of the upper flow system based on acceptable yield assumptions). The more likely future scenarios involve domestic use of ground water from the Burro Canyon system or water being supplied by the City of Monticello.

2. There must be a substantive exceedance of a human health risk benchmark.

Figure 4.6-3 outlines the conceptual regulatory decision scenario for the upper flow system. Exceedance of an applicable requirement or a relevant and appropriate requirement will indicate a finding of regulatory impact. The formal and final assessment of ARARs is not completed until the ROD (40 CFR Part 300). However, Appendix A presents a preliminary evaluation of potential ARARs. For purposes of planning in this work plan, the chemical specific benchmarks used in Table 4.6-4 can be considered a preliminary assembly of potential ARARs.

Figure 4.6-4 outlines the conceptual risk assessment decision scenario for surface water and sediment of Montezuma Creek leading to a decision of acceptable or unacceptable human health risk. Two variables must both be present spatially and temporally in order for an unacceptable risk to be reasoned; thus:

1. There must be human exposure in accordance with the assumptions of the recreational exposure scenario.

2. There must be a substantive exceedance of a human health risk benchmark.

Figure 4.6-5 displays the conceptual regulatory decision scenario for Montezuma Creek. Exceedance of a requirement that is applicable, *or* a relevant and appropriate requirement will indicate a finding of regulatory impact. As with the upper flow system, formal and final assessment of ARARs is not completed until the ROD. Chemical specific benchmarks shown in Table 4.6-5 for surface water and Table 4.6-6 for sediment/soil can be considered as a preliminary assembly of potential ARARs for purposes of project planning

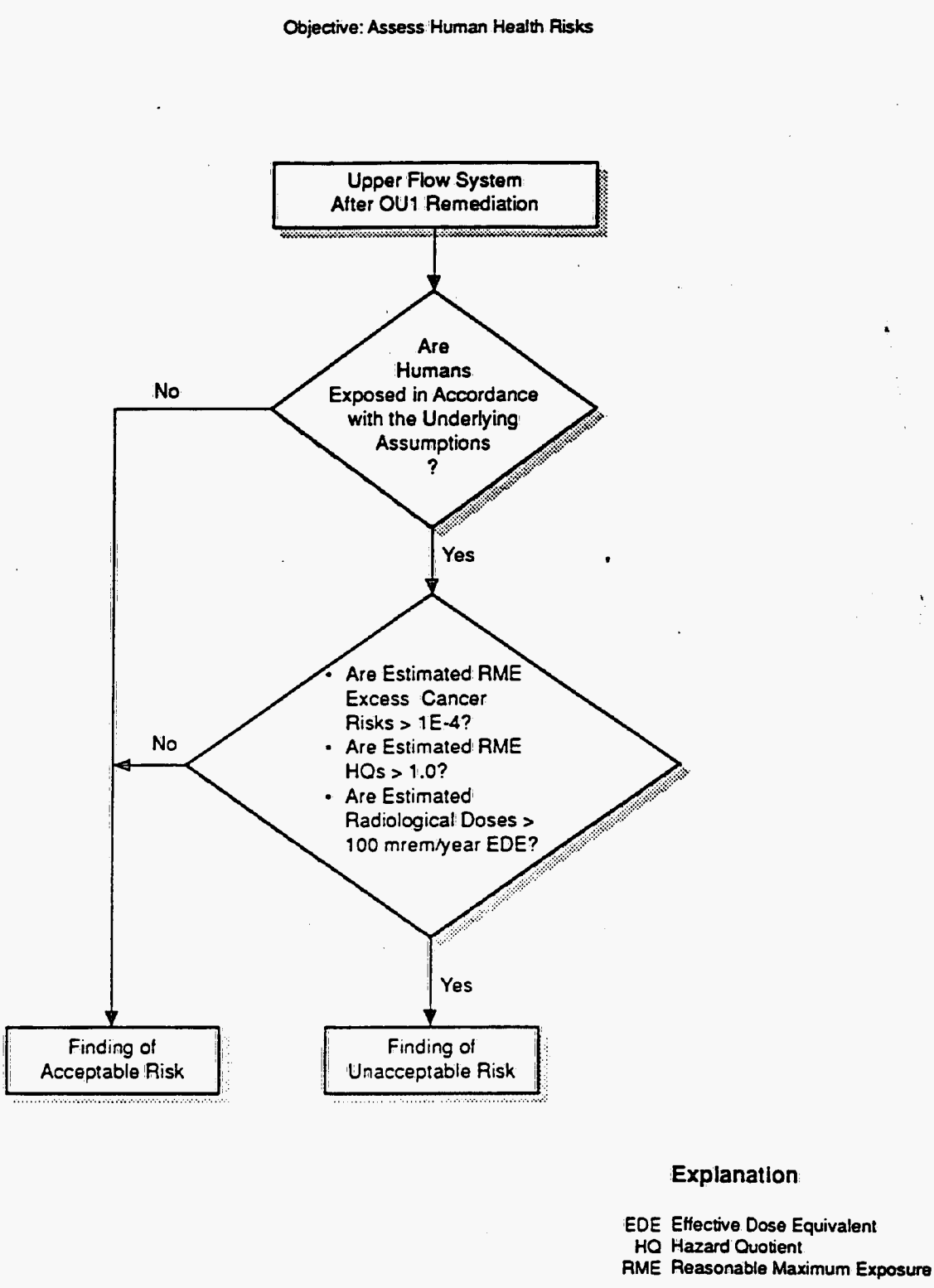


Figure 4.6-2. Upper Flow System - Future Use Risk Assessment Decision Diagram

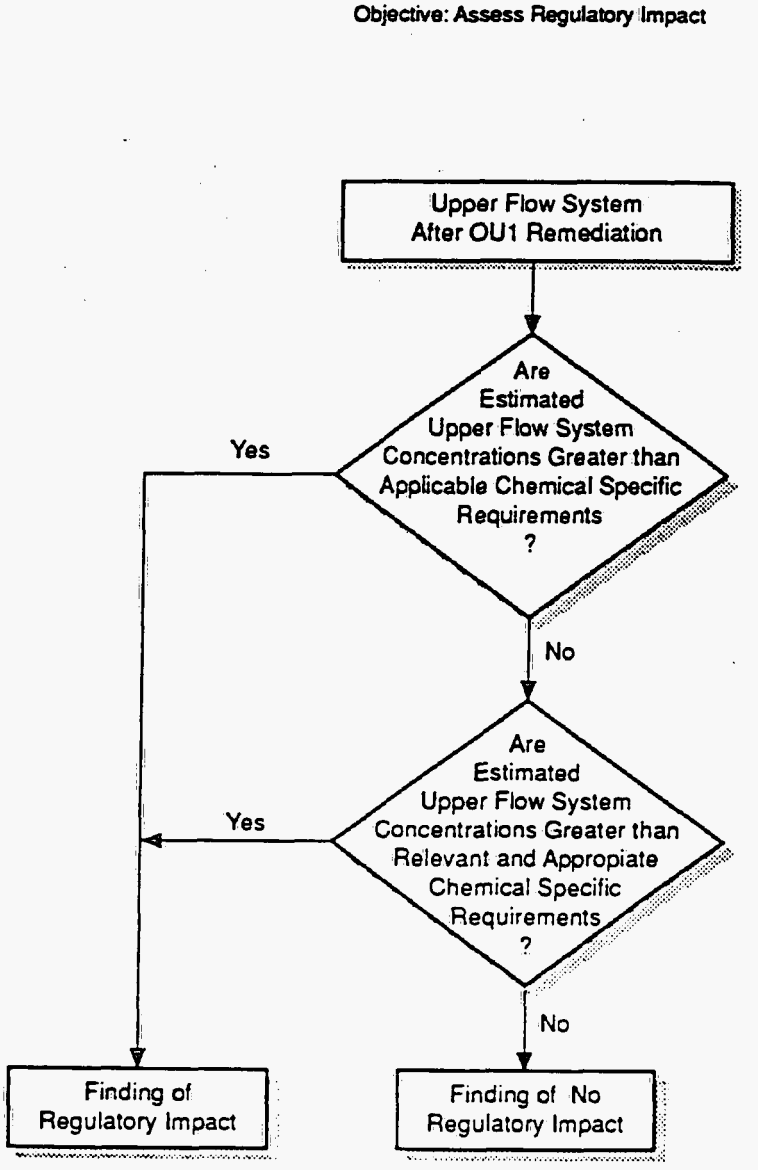
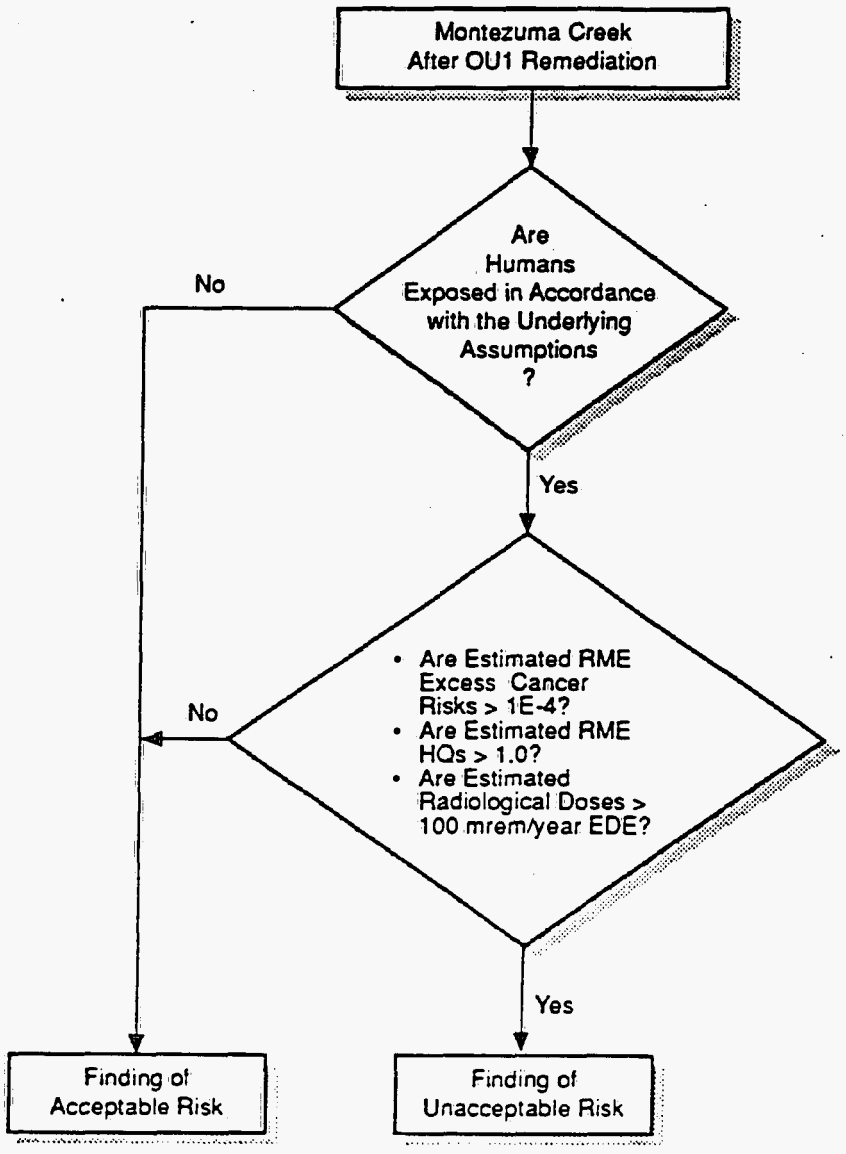


Figure 4.6-3. Upper Flow System - Future Use Regulatory Assessment



Explanation

EDE Effective Dose Equivalent
HQ Hazard Quotient
RME Reasonable Maximum Exposure

Figure 4.6-4. Montezuma Creek - Future Use Risk Assessment Decision Scenario

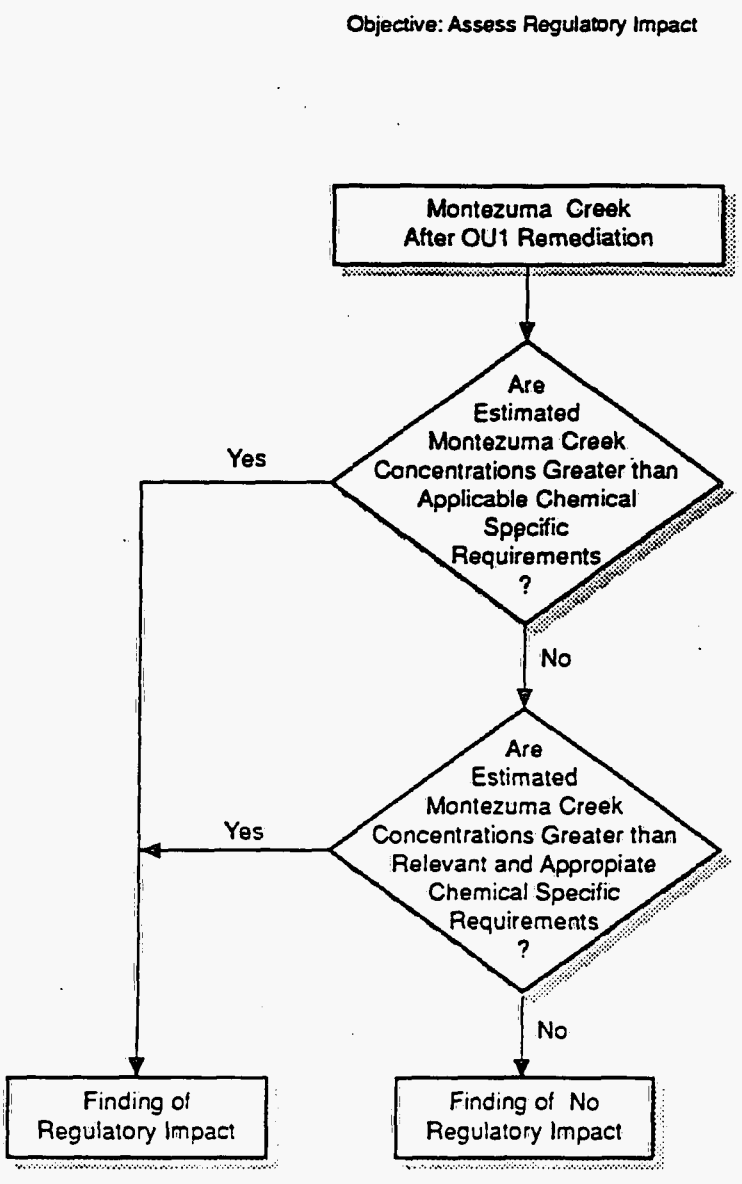
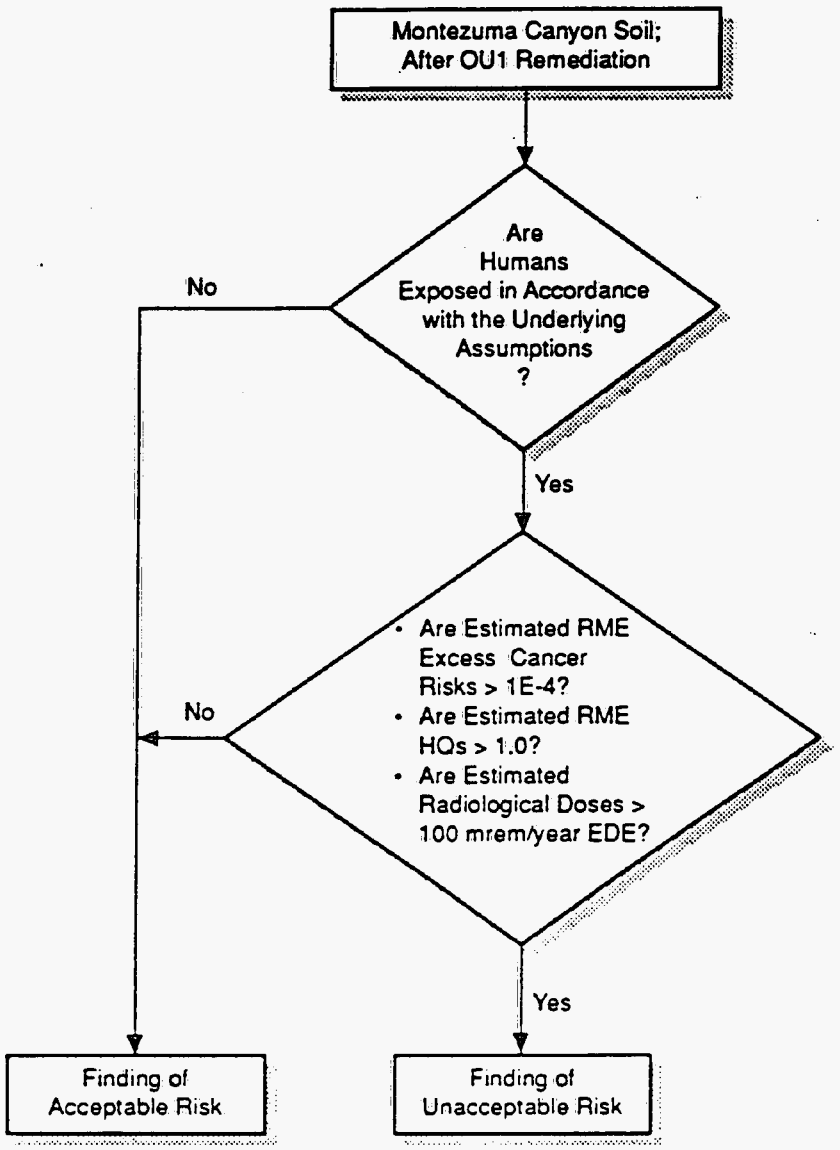


Figure 4.6-5. Montezuma Creek - Future Use Regulatory Assessment



Explanation

EDE Effective Dose Equivalent
HQ Hazard Quotient
RME Reasonable Maximum Exposure

Figure 4.6-6. Montezuma Canyon Soil - Current and Future Use Risk Assessment Decision Scenario

Objective: Assess Regulatory Impact

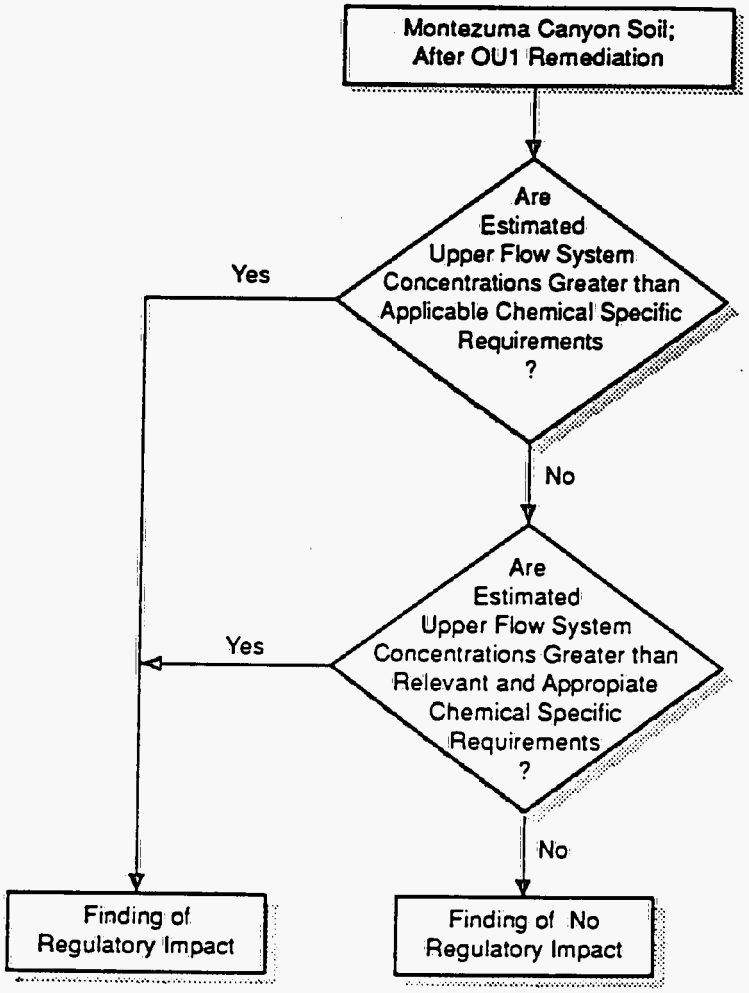
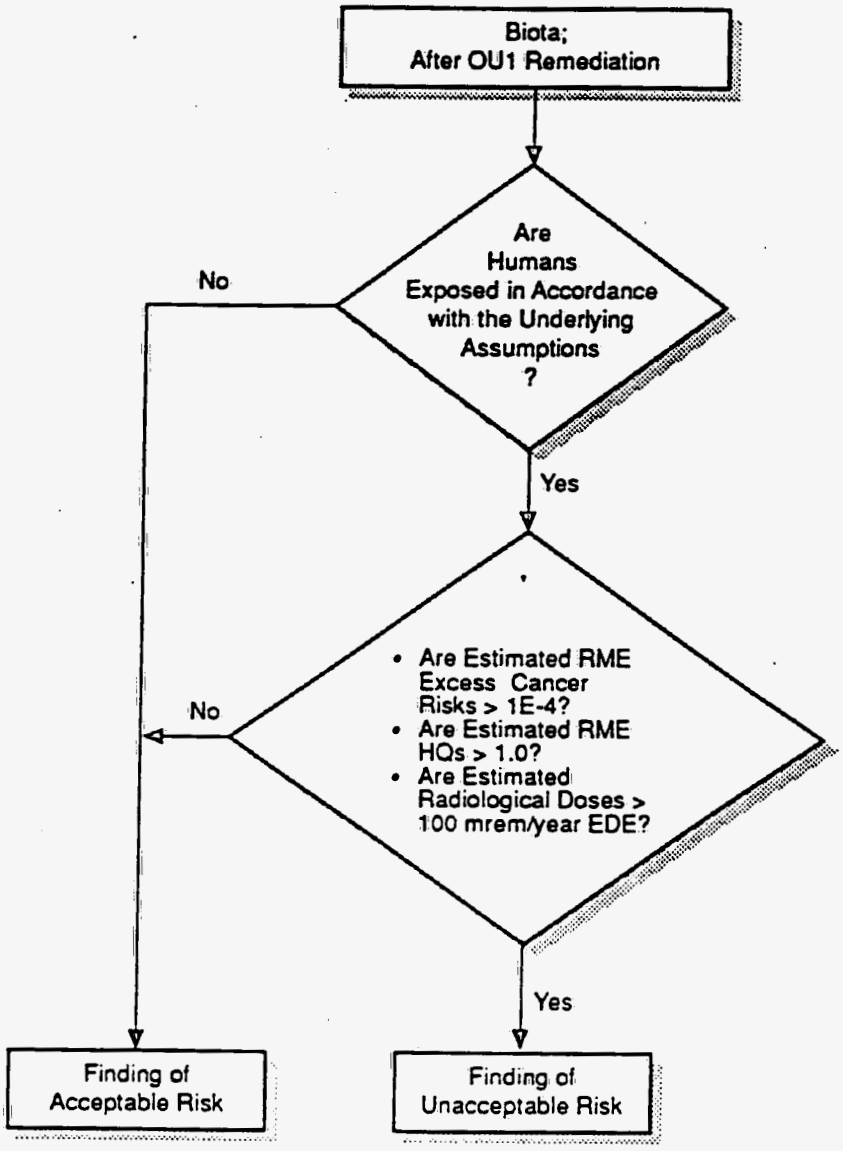


Figure 4.6-7. Montezuma Canyon Soil - Current and Future Regulatory Assessment



Explanation

EDE Effective Dose Equivalent
HQ Hazard Quotient
RME Reasonable Maximum Exposure

Figure 4.6-8. Biota - Current and Future Use Risk Assessment Decision Scenario

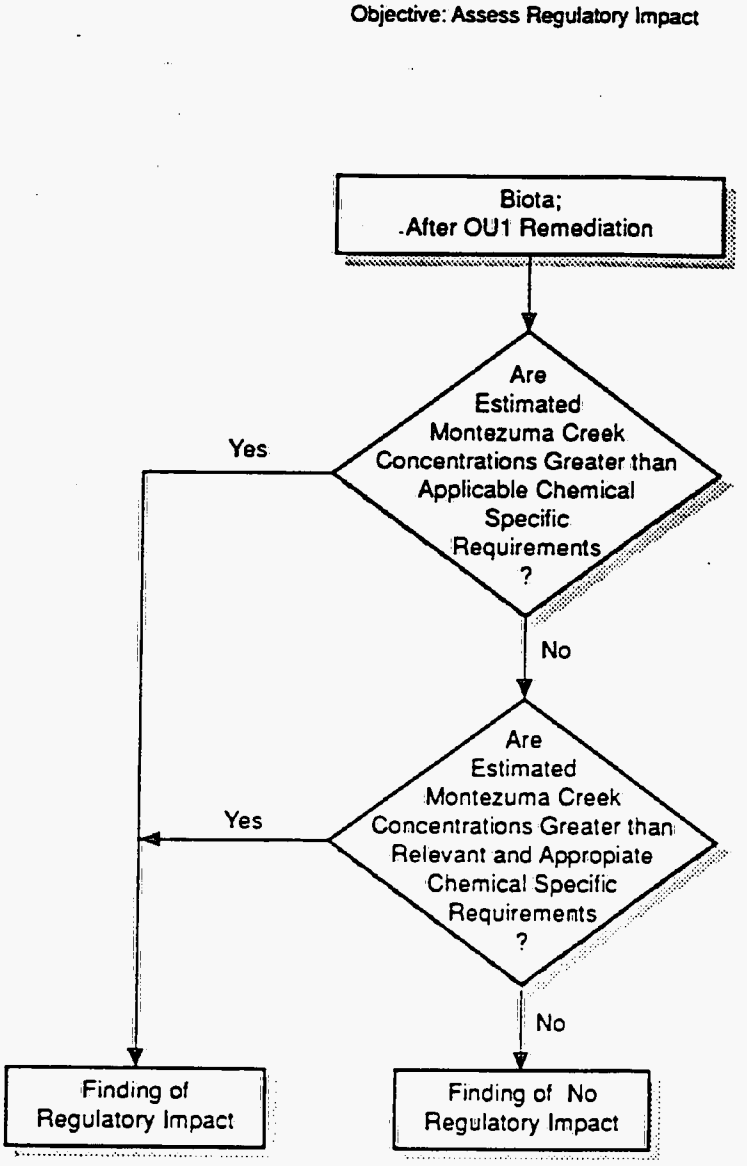


Figure 4.6-9. Biota - Current and Future Use Regulatory Assessment

Figure 4.6-6 outlines the conceptual risk assessment decision scenario for soil of Montezuma Canyon leading to a decision of acceptable or unacceptable human health risk based on the following two variables:

1. There must be human exposure in accordance with the assumptions of the recreational, agricultural, and residential scenarios.

2. There must be a substantive exceedance of a human health risk benchmark.

Figure 4.6-7 displays the conceptual regulatory decision scenario for human exposure to soil in Montezuma Canyon. Exceedance of a requirement that is applicable, or a relevant and appropriate requirement (i.e., human health benchmarks shown in Table 4.6-4) will indicate a finding of regulatory impact.

Figure 4.6-8 outlines the decision scenario for biota exposure media represented by cattle that graze in Montezuma Canyon. The two variables that must be present for an unacceptable risk to be reasoned are as follows:

1. There must be human exposure in accordance with the assumptions of the agricultural scenario.

2. There must be a substantive exceedance of a human health risk benchmark.

Figure 4.6-9 shows the conceptual regulatory decision scenario for human exposure to cattle that graze in Montezuma Canyon. Exceedance of a requirement that is applicable, or a relevant and appropriate requirement (if one can be established) will indicate a finding of regulatory impact.

Step 3 (Identify Inputs to the Decision). Inputs to the decisions (shown on Tables 4.6-9, 4.6-10, 4.6-11, 4.6-12, and 4.6-13) include existing and new sample analytical data, ground-water flow and solute transport modeling results, and future land and water use information. Analytical detection limits for existing and new data are included under inputs because they must be considered when determining adequacy of data for decision making. Sources of data inputs as well as sampling and analytical techniques used for existing and proposed samples are also referenced in Tables 4.6-9, 4.6-10, 4.6-11, 4.6-12, and 4.6-13.

To support a decision of potential unacceptable risk in the hypothetical future risk scenario for ground water, additional information is needed to assess whether and when human exposure will occur and to evaluate what the chemical specific concentration profiles over time will be.

The following additional information describing population dynamics is needed:

- Assessment of expected growth pressures in the Monticello area and resultant planned use of the study area for residential use in the next 50 years.

- Expected demands for upper flow system ground water in the study area to support domestic use in the next 50 years.

An evaluation of chemical specific concentration profiles is necessary to perform a future use quantitative risk assessment. As discussed elsewhere in this work plan (Task 6 Ground-Water Modeling), a ground-water and solute-transport model will be used to estimate the effects on upper flow system chemical concentrations resulting from remediation of OU I. One output from this model will be concentration versus time profiles that can be used as input to risk assessment equations (Section 4.6.3). Figure 4.6-10 is an example of concentration and risk profiles over time as they could be presented in the BRA.

For surface water and sediment, information must be provided to establish whether, and when human recreational exposure will occur, and the chemical specific concentration profiles over that time frame.

There is good certainty in assuming that Montezuma Creek east of the MMTS will be used for recreational purposes because this is its current use. There is less certainty that the reach of Montezuma Creek through the MMTS will be used for recreational purposes. Overall, the greatest uncertainty stems from assuming that recreational use will be the only use of Montezuma Creek. Thus, information should be produced to address development of Montezuma Creek for uses other than recreational including:

- Expected growth pressures in the Monticello area and resultant planned uses of Montezuma Creek including domestic supply.

- Montezuma Creek use attainability based on hydrologic viability of the upstream watershed.

As discussed elsewhere in this work plan (Task 6 Ground-Water Modeling), a ground water and surface water solute transport model will be used to estimate the effects of remediation of OU I. One output from this model will be concentration versus time profiles that can be used as input to risk assessment equations (See Figure 4.6-10). Data use objectives for solute transport modeling are identified in Table 4.6-9 and are discussed later in this section. Sampling data will be obtained for potential contamination of cattle (Section 4.6.4.3).

Data action levels are the input criteria upon which the decision making is based. Data action levels referenced on Tables 4.6-9, 4.6-10, 4.6-11, 4.6-12, and 4.6-13 include background chemical concentration thresholds, preliminary human health benchmark concentrations, ARARs, and radiation dose limits established under DOE Order 5400.5.

Years	ug/l	Excess Risk
0	20.0	4.0E-04
0.5	16.0	3.2E-04
1	12.8	2.6E-04
1.5	10.2	2.0E-04
2	8.2	1.6E-04
2.5	6.6	1.3E-04
3	5.2	1.0E-04
3.5	4.2	8.4E-05
4	3.4	6.7E-05
4.5	2.7	5.4E-05
5	2.1	4.3E-05
5.5	1.7	3.4E-05
6	1.4	2.7E-05
6.5	1.1	2.2E-05
7	0.9	1.8E-05
7.5	0.7	1.4E-06
8	0.6	1.1E-06
8.5	0.5	9.0E-06
9	0.4	7.2E-06
9.5	0.3	5.8E-06
10	0.2	4.6E-06
10.5	0.2	3.7E-06
11	0.1	3.0E-06
11.5	0.1	2.4E-06
12	0.1	1.9E-06

Hypothetical Representation Of
RME With Upper and Lower Bounds
Typical of Future Case Modeling

Figure 4.6-10. Typical Time Versus Concentration and Risk Profiles

Step 4 (Define the Study Boundaries). The spatial and temporal boundaries of investigative activities for the human health risk assessment are identified under the heading Study Boundaries in Tables 4.6-9, 4.6-10, 4.6-11, 4.6-12, and 4.6-13.

For the upper ground-water flow system, the boundaries correspond with that portion of the system where ground water could be accessed for domestic use. As indicated on Table 4.6-6, these are defined as:

- The upper flow system above the 100-year floodplain underlying the approximate area east of Highway 191, through the MMTS, and proceeding east of the MMTS to the locale where Montezuma Canyon narrows. This area is comparatively flat and could support construction of a residence. Eastward into the canyon is not suitable for such construction because of limited access and lack of suitable construction areas above the 100-year floodplain.

- As discussed in Section 4.2, the reasonable time required for unrestricted rate use will be determined. This time frame will be investigated during the modeling exercise to determine if it adequately profiles contaminant dissipation after remediation of the MMTS, provides an ample time window to consider long term development in the area, permits an adequate number of years for regulatory review under CERCLA (required at least every 5 years), and is compatible with any supplemental standards or ARAR waivers that may allow contaminants to be left in place at other locations above risk-based levels.

For the Montezuma Creek system, the boundaries correspond with that portion of the surface water and sediment that could be accessed for consumption through recreational use. As indicated on Table 4.6-10, these are defined as

- The reach of Montezuma Creek from Highway 191 to approximately 0.5 mile below the confluence of Vega Creek.

- As discussed in Section 4.2, the reasonable time required for unrestricted rate use will be determined. This time frame will be investigated during the modeling exercise to determine if it adequately profiles contaminant dissipation after remediation of the MMTS, permits assessment of then first available potential generation of exposed populations, provides an ample time window to consider long term development in the area, permits an adequate number of years for regulatory review under CERCLA (required at least every 5 years), and is compatible with any supplemental standards or ARAR waivers that may allow contaminants to be left in place at other locations above risk-based levels.

Step 5 (Develop a Decision Rule). This step integrates the decision and data inputs resulting in statements of alternative actions.

A finding of appreciable risk, as illustrated on Figures 4.6-2, 4.6-4, 4.6-6, and 4.6-8, requires that (1) human exposure occurs (or is reasonably likely to occur) and (2) exposure concentrations generate multipathway risk estimates exceeding 1E-4, HQ's greater than 1.0, or EDE's in excess of 100 mrem/year. The following decision rule accompanies the above-referenced figures.

Step 6 (Limits on Decision Errors). The purpose of this step is to help ensure that the quality of data is appropriate to make confident decisions. Confidence in decision making relating to sample size is discussed below.

The decision framework as developed in Figure 4.6-2 is based on numerical modeling results and is subject to uncertainties in the model concentration estimates. Uncertainties in environmental modeling results have been addressed in a guidance and specification document published by the International Atomic Energy Agency entitled *Evaluating the Reliability of Predictions Made Using Environmental Transfer Models* (IAEA 1989). Human health risk analysis is also a form of modeling and it is subject to uncertainties, including those arising from variation in the exposure input parameters. Thus, there are two sources of error in the overall comparison decision method.

In general, different combinations of human exposure factors (e.g., intake rates, exposure durations, etc.) can produce about a factor of ten variability in risk estimates. For example, a mean risk estimate of 1E-5 (excess cancer) could vary from 1E-6 to 1E-4 by varying exposure factors within their envisioned ranges. It is sensible that estimated exposure point concentrations from modeling should contribute no more than a factor of ten to the overall risk estimate. Thus, ground-water modeling concentration estimates that are within an overall factor of ten of the measured concentration range of a target will not increase the uncertainties.

Acceptable ground-water concentrations for use in the human health risk assessment process should strive to conform to the following:

Concentration estimates acceptable range =

Lower range measurement / 3.33
Upper range measurement * 3.33

This is illustrated in Table 4.6-14.

Table 4.6-14. Example of Acceptable Error Assessment for Ground-Water Concentration Estimation and Decisions

Measured Ground-Water Contaminant Concentration(s) (Base Case)	Target Acceptable Modeled Ground-Water Contaminant Concentration
50 μg/l	15 μg/l to 150 μg/l*
40 μg/l to 60 μg/l	12 μg/l to 200 μg/l'
25 μg/l to 75 μg/l	8 μg/l to 250 μg/l'

μg/l Micrograms per liter

* Reflects the factor of 10 uncertainty in exposure factor variables.

' Reflects the factor of 10 uncertainty in exposure factor variables and the true variability in ground-water concentrations.

Limit on decision error: Ground-water concentration estimates should be within a factor of ten of the observed measured range for the baseline existing case.

When expressed in this manner, modeling uncertainties are treated similar to the uncertainty in other measurements such as analytical results from sampling. This approach to establishing limits on decision errors stemming from modeling and exposure factors is analogous to establishing bounding statistical performance objectives recommended in EPA guidance on *Data for Data Usability in Risk Assessment* (EPA 1992b).

Analogous to the upper flow system, the decision framework developed in Figures 4.6-4 and 4.6-5 is partially based on ground-water modeling results to predict surface water concentrations, and is subject to uncertainties in the model concentration estimates. There are two sources of error in the overall comparison decision method: (1) exposure variables, and (2) the accuracy of modeled exposure concentration profiles.

It is sensible that estimated surface water exposure point concentrations from modeling should contribute no more than exposure factor variables. Thus, Montezuma Creek modeling concentration estimates that are within an overall factor of 10 of the measured concentration range for target reaches should not generate any more error than the error inherent in the exposure factors.

Acceptable surface water concentrations for use in the human health risk assessment process should strive to conform to the following:

Concentration estimates acceptable range =

Lower range measurement / 3.33
Upper range measurement * 3.33

Surface water concentration estimates should be within a factor of ten of the observed measured range for the baseline existing case.

Table 4.6-14 presents an example of this approach.

This approach to establishing limits on decision errors stemming from modeling and exposure factors is analogous to establishing bounding statistical performance objectives recommended in EPA guidance on *Data for Data Usability in Risk Assessment* (EPA 1992b).

Step 7 (Optimize the Design for Obtaining Data). The optimized design for the OU III human health risk assessment investigation is presented in this Work Plan.

4.6.4.2 Chemicals of Potential Concern

This section summarizes the chemicals identified as COPCs for human health. COPCs are identified for human health in accordance with EPA Region 8 guidance presented in *Evaluating and Identifying Contaminants of Concern for Human Health* (EPA 1994a). A detailed description of the COPC screening process used for OU III is provided in Appendix E.

The COPC identification process used for OU III parallels EPA National Guidance (EPA 1989c) as well as that of EPA Region 8 (EPA 1994a). The key considerations factored into the identification include: Role as essential dietary nutrients, comparisons to background levels, and comparison to health protective benchmark concentrations and potential regulatory criteria.

For OU III, the COPC identification process is being conducted in two phases. Phase I, implemented during Work Plan development, uses conservative screening techniques. COPCs identified in Phase I form the basis for the RI chemical analysis program. Phase I of the process is generally conservative, and therefore, the list of COPCs identified during Phase I probably includes more chemicals than are necessary to characterize the human health risks associated with OU III. The list will be refined during Phase II of the identification process. Phase II will be implemented following receipt and interpretation of RI field and analytical data. An important contribution to Phase II will be incorporation of data collected from the reference area. COPCs resulting from the Phase II effort will form the basis for the human health component of the baseline risk assessment.

The COPCs for human health identified on the basis of the Phase I screening process are listed in Table 4.6-15. As shown, COPCs for human health are identified for the upper ground-water flow system, Montezuma Creek surface-water system, and Montezuma Creek sediment/soil. As discussed in Section 4.6.3, preliminary computations performed using historical site air quality data indicate that risks associated with the air pathway are within acceptable limits; thus, no COPCs have been identified for air.

Table 4.6-15. Chemicals of Potential Concern for Human Health[a]

Constituent	Upper Ground-Water Flow System	Montezuma Creek Surface Water	Montezuma Creek Sediment/Soil
Aluminum	Yes	No	No
Arsenic	Yes	Yes	Yes
Boron	Yes	No	No
Copper	No	No	Yes
Manganese	Yes	No	Yes
Molybdenum	Yes	Yes	No
Selenium	Yes	Yes	No
Sodium	Yes	No	No
Sulfate	Yes	Yes	No
Tin	Yes	Yes	No
Uranium	Yes	Yes	Yes
Vanadium	Yes	No	Yes
Pb-210	Yes	No	Yes
Ra-226	Yes	No	Yes
Th-230	No	No	Yes
Gross Alpha	Yes	Yes	No
Gross Beta	Yes	Yes	No
Po-210	Yes	No	No
Rn-222	No	Yes	No
U-234	Yes	Yes	No
U-235	Yes	Yes	Yes
U-238	Yes	Yes	Yes

[a]See Appendix C for further detail.

4.6.4.3 Assessment Program

The data needed to assess risk to human health is already available, will be collected during annual monitoring, or will be gathered to support the ecological risk assessment. One possible exception to this is the data needed to assess risks to humans resulting from the ingestion of cattle tissue. The CSM indicates that ingestion of cattle tissue is a complete pathway. DOE may propose a cattle sampling program to assess exposure comparison between off-site and on-site analyte concentrations in tissues if uncertainties in the risk and remediation assessment are

unacceptable to support the decision process. Specifically, if the results of the RI/FS suggests that no action is warranted, DOE will re-evaluate the need to further assess risk associated with the soil and sediment pathway including collection of beef tissue as appropriate. If DOE, in conjunction with the EPA and the State, determine that sampling is warranted, statement of work and sampling procedures will be documented as a Program Directive that will become an addendum to this Work Plan.

4.6.4.4 Analytical Program

Soil, sediment, surface water, and ground water will be collected and analyzed for metals and radionuclides to support the HHRA. Tables 4.6-16 through 4.6-18 lists the COPCs identified in Table 4.6-15, the method of analysis, and the method detection limit for soil and sediment, surface and ground water, respectively. When a chemical (such as aluminum) has been identified as a COPCs in one medium (ground water) it becomes by default a COPC in the other media: soil, sediment, surface water, and cattle. The MDLs listed in these tables are those which, on the basis of the preliminary HHRA, must be achieved so that the analytical data are adequate for human health risk assessment use.

Table 4.6-16. Soil and Sediment Analytical Parameters, Methods of Analysis, and Method Detection Limits

Analytical Parameter[1]	Method of Analysis	Method Detection Limit
Metals		*mg/kg*
Aluminum	CLP Method 200.7	40
Arsenic	EPA SW-846 6020	2.0
Boron	CLP Method 200.7	1.0
Copper	CLP Method 200.7	5.0
Manganese	CLP Method 200.7	3.0
Molybdenum	CLP Method 200.7	10
Selenium	EPA SW-846 6020	1.0
Tin	EPA SW-846 6020	2.0
Uranium[2]	Not Applicable	Not Applicable
Vanadium	CLP Method 200.7	10
Radionuclides		*pCi/g*
Lead-210	Geotech Method RC-6	2.0
Potassium-40	Geotech Method GS-1	10
Radium-226	Geotech Method GS-1	1.0
Thorium-230	EPA SW-846 6020	1.0

Table 4.6-16. Soil and Sediment Analytical Parameters, Methods of Analysis, and Method Detection Limits (Continued)

Analytical Parameter[1]	Method of Analysis	Method Detection Limit
Thorium-232	**Geotech Method GS-1**	**1.0**
Uranium-234	**EPA SW-846 6020**	**1.0**
Uranium-235	**EPA SW-846 6020**	**1.0**
Uranium-238	**EPA SW-846 6020**	**1.0**
Other		
Sodium	**CLP Method 200.7**	
Sulfate	**EPA Method 300**	

[1]COPCs are in bold-face type.
[2]Uranium isotopes will be measured rather than total uranium. Uranium is approximately composed of 99.3 percent uranium-238.

Table 4.6-17. Surface-Water and Ground-Water Analytical Parameters, Methods of Analysis, and Method Detection Limits

Analytical Parameters[1]	Method of Analysis	Method Detection Limit
Metals		*µg/L*
Aluminum	**EPA SW-846 6020**	**10**
Arsenic	**EPA SW-846 6020**	**1.0**
Boron	**CLP Method 200.7**	**50**
Copper	**CLP Method 200.7**	**5.0**
Manganese	**CLP Method 200.7**	**1.0**
Molybdenum	**EPA SW-846 6020**	**10**
Selenium	**EPA SW-846 6020**	**1.0**
Tin	**EPA SW-846 6020**	**10**
Uranium[2]	**Not Applicable**	**Not Applicable**
Vanadium	**CLP Method 200.7**	**10**
Radionuclides		*pCi/L*
Gross Alpha	**Geotech Method RC-3**	**1**
Gross Beta	**Geotech Method RC-3**	**1**
Lead-210	**Geotech Method RC-6**	**2.0**
Radium-226	**Geotech Method RC-5**	**0.5**

Table 4.6-17. Surface-Water and Ground-Water Analytical Parameters, Methods of Analysis, and Method Detection Limits (Continued)

Analytical Parameters[1]	Method of Analysis	Method Detection Limit
Radon-222	Geotech Method RC-17	20
Thorium-230	EPA SW-846 6020	1
Uranium-234	EPA SW-846 6020	1
Uranium-235	EPA SW-846 6020	1
Uranium-238	EPA SW-846 6020	1
Other		*mg/L*
Sodium	CLP Method 200.7	0.6
Sulfate	EPA Method 300	0.2

[1] COPCs are in bold-face type.
[2] Uranium isotopes will be measured rather than total uranium. Uranium is approximately composed of 99.3 percent uranium-238.

In addition to the metals and radionuclides COPCs, knowledge of the naturally occurring radionuclides K-40 and TH-232 (radionuclides that are not part of the uranium decay series and not a component of uranium ore) of soil and sediment are required to determine background radioactivity.

Samples of soil, sediment, and surface water, and ground water will be submitted to the GJPO Analytical Laboratory for analysis. The CLP methodologies will be the primary methodologies used for metals analyses in soil, surface-water and ground-water media. When TBVs require MDLs less than what can be achieved by CLP-RAS, then other EPA methods (i.e., SW-846) are substituted. Data deliverables will be similar to CLP-RAS.

Radionuclide analyses of samples collected in sediment, soil, surface water, and ground water will be by the GJPO Analytical Laboratory's standard methods and procedures. The analytical technique used to measure each of the radionuclide activities is presented in Table 4.6-18.

Table 4.6-18. Number of Beef Tissue Samples for the Human Health Risk Analysis

	Up Canyon	Down Canyon	Reference Area	Local
Muscle	3	3	3	3
Liver	3	3	3	3

Up Canyon is above (west) of the Montezuma Canyon narrows.
Down Canyon is below (east) of the Montezuma Canyon narrows.
Reference Area for this sampling is tentatively in Verdure Canyon.
Local is beef tissue purchased in a local food store.

Acceptance criteria for laboratory analyses, including calibration of laboratory equipment and internal laboratory QC checks (i.e., reagent blanks, duplicates, matrix spikes, matrix spike

duplicates, etc.) are specified by the analytical method. Documentation is maintained for all analytical results as a means of supporting reported results and identifying potential causes for measurement problems. The FSP lists for each media the determination method, method detection limit, requirements for sample containers, sample volume, preservation, and holding times.

During analytical data review it will be verified that the laboratories performed the methods requested and followed method QA/QC. The data will be validated by reviewing raw data and supporting field and laboratory information to determine if they are of adequate quality for their intended purposes. Verification and validation forms will be prepared as a means of documenting the review process.

4.7 Task 6: Ground-Water Modeling

Ground-water modeling will support the ecological and human health risk assessments and predict the length of time required for COPC concentrations to dilute by hydrodynamic dispersion to levels that are protective of human health and the environment and meet the other reference criteria (MCLs, ARARs, background concentrations, risk-based concentrations, and other TBC criteria). Modeling will support the risk assessments by predicting future exposure point concentrations of selected COPCs in surface water and ground water. If risks to human health or the environment are excessive or the predicted time required for COPC concentrations to meet the reference criteria is deemed unreasonable by DOE, EPA, and the State, then modeling will also be used to support evaluation of response action alternatives under the FS.

Ground-water modeling results will also be used in the risk assessment to establish metals cleanup criteria for millsite remediation. The criteria will be established by predicting source term for the selected metals at the millsite for which predicted exposure point concentrations in surface water and ground water pose acceptable human health and the environmental risk. Source term is a known or estimated concentration of one or more contaminants in surface or ground water at a specific location. The actual source of the contamination may be leachate from unsaturated soils, dissolution of contaminants within saturated soils, leakage of solute from a man-made structure, or even natural background concentrations of contaminants from precipitation or upgradient ground-water sources. In addition, the hydrogeologic conceptual site model will be refined if it is determined during the modeling process that refinements are necessary.

Modeling will be accomplished through development and application of a MODFLOW/MT3D ground-water flow and transport model. This model was selected because saturated ground-water flow is the primary flow and transport process within OU III. MODFLOW and MT3D have been proven to be effective codes for modeling two and three-dimensional saturated flow and transport, respectively. In addition, a one-dimensional variably saturated flow and transport model, HYDRUS, will be used. HYDRUS model results will provide an estimate of source term input to the MT3D code. Modeling results will provide direct predictions of

COPC concentrations in ground water. Future concentrations in surface water will be estimated using specific stream cell output from the model.

4.7.1 Data Quality Objectives

Ground-water modeling has two primary objectives that are to (1) predict future exposure point concentrations of select COPCs in surface water and ground water and (2) predict the time required for exposure point concentrations of select COPCs in surface water and ground water to dilute by hydrodynamic dispersion to levels that meet the reference criteria. In addition, modeling will also be conducted to accomplish three secondary objectives including to (1) predict exposure point concentrations based on varying source terms for select metals remaining at the millsite after remediation, (2) predict exposure point concentrations for select COPCs in surface water and ground water for response action alternatives, and (3) support or potentially confirm the validity of the hydrogeologic conceptual site model and, if necessary, refine the model.

The DQO process was used during the scoping effort for ground-water modeling. The DQO process was used to identify decisions to be made on the basis of model results, identify the data needed to accomplish model objectives, define geographic and temporal boundaries, and to assess the uncertainty associated with model results.

The decisions to be made on the basis of model results were formulated based on the objectives listed above. However, formulation of decisions specific to the model was not warranted for the modeling objectives that involve direct support to other OU III tasks (i.e., support for risk assessment studies [primary objective 1] and for evaluation of response action alternatives [secondary objective 2]). The following decisions were formulated for the remaining three objectives:

- At what point in time are exposure point concentrations in surface water and ground water predicted to dilute by hydrodynamic dispersion to levels meeting the reference criteria.

- Will metal concentrations in sediment/soil remaining at the millsite after implementation of the ROD for OUs I and II be protective of surface water and ground water?

- Do model results support the current hydrogeologic conceptual site model for OU III?

The DQO process was also used to identify the data needed to ensure that modeling objectives can be accomplished. The data needed were grouped into four general categories: (1) data needed to develop a hydrogeologic conceptual site model, (2) data needed to understand the current distribution of chemical constituents in surface water, ground water, sediment, and soil, (3) data needed as direct input to the model, and (4) data needed to assess model results. The degree to which existing site data could be used to address the needs in each category was evaluated by assessing the quantity and quality of existing data and the spatial and temporal distributions of the data. Following an evaluation of existing data, new data to be collected in support of the ecological and human health risk assessments were reviewed to assess how these

data could be used to support existing data and address any of the remaining data needs. The evaluation of existing data and review of proposed new data resulted in the following findings:

- An adequate hydrogeologic conceptual site model can be developed on the basis of existing site data. The hydrogeologic conceptual site model is discussed in Section 4.7.3.
- A sufficient amount of existing data is available to describe distributions of chemical constituents in surface water and ground water within OU III and in soil/sediment at the millsite. Additional data are needed to adequately assess the distribution of chemical constituents in soil/sediment in the focused study area; however, these data will be obtained under the study designed for ecological risk assessment. The use of existing and new analytical data in relation to source term determinations is discussed in Section 4.7.8.1, and the data to be used to support transport model calibration is discussed in Section 4.7.9.

- Most of the data needed for model input can be provided by existing data. Some additional data will be needed to address specific parameters. Most of these additional data will be obtained from available literature. However, some new site-specific data will be required. Specifically, discharge measurements are needed to assess potential leakage from Hall's Ditch and sieve or retention-curve data are needed to estimate soil properties. Data sources for model input parameters are discussed in Sections 4.7.6 through 4.7.9.

The geographic area within which model decisions will apply is defined by the model domain. Model domain boundaries are described in Section 4.7.5. The time frame for model predictions will extend from the time that millsite remediation is completed to a specified time (e.g., 70 years) after millsite remediation. The model will be developed using site data obtained over the past 10 years; however, an emphasis will be placed on data gathered during the initial stage of the OU III RI (see *Baseline Characterization Data Summary*, DOE 1994b). Greater emphasis will be given to baseline characterization data because these data have been reviewed with respect to field procedures, analytical methodologies, and analytical raw data. The older data have not been reviewed in an equivalent manner.

The uncertainty associated with model results was also considered during the implementation of the DQO process. Model uncertainty is very difficult to quantify because modeling results are dependent on complex interactions among numerous estimated variables. It is generally presumed that model uncertainty can be minimized by increasing model complexity (refinement in the discretization of space and time). However, resource requirements also increase as the model becomes more complex. Therefore, a balance must be reached between the degree of complexity used to minimize uncertainty and the degree of complexity required to represent flow and transport processes at the site.

As a result, model uncertainty is commonly evaluated on the basis of qualitative assessments. Attempts to minimize model uncertainty generally involve an assessment of the quality of data to be used as input to the model. These assessments typically include evaluating the procedures followed to collect and analyze the data to be used as input parameters. Model uncertainty is also assessed during model calibration, which serves as a means of measuring

the predicted uncertainty of model output. In addition, sensitivity analysis can be used as a means of assessing the impact of input variability/uncertainty.

Attempts to minimize the uncertainty associated with model results for OU III focuses on ensuring that the existing site data to be used as model input were obtained at locations sufficient for modeling and in accordance with established collection and analysis procedures. The use of existing data to support the model is further discussed in Sections 4.7.6 through 4.7.9. After the model has been developed, the uncertainty of predicted results will be further assessed on the basis of calibration results. Sensitivity analysis will be performed to assess the impact of input variability/uncertainty.

If the DOE, EPA, and the State determine that the uncertainty of model parameters and outcome need to be quantified to support a defensible decision, the use of MODFLOWP, a parameter estimating version of MODFLOW, may be initiated. MODFLOWP performs statistical calculations that quantify uncertainty associated with model parameters.

4.7.2 Technical Approach

The ground-water modeling technical approach was designed with the concurrence of the EPA and State and consists of the following general steps:

1) Define modeling objectives.
2) Evaluate conceptual model.
3) Estimate water budget.
4) Define model domain, select numerical model codes, and procurement of materials.
5) Develop numerical flow models (HYDRUS and MODFLOW).
6) Conduct initial flow simulations, calibration and sensitivity analysis.
7) Develop numerical transport models (HYDRUS and MT3D).
8) Conduct initial transport simulations, calibration and sensitivity analysis.
9) Conduct final transport simulations and evaluate range of outcome (quantitative and qualitative).
10) Document results during and at conclusion of modeling effort.

Steps 1, 2, and 4 have been completed. Some of these tasks and each of the remaining general tasks include specific subtasks that are discussed in the following sections. The development of the numerical flow and transport models, for example, are among the most laborious tasks and include subtasks such as code selection, grid and boundary condition development, and parameter estimation. This work entails significant data reduction, compilation, and interpretation. Some technical details of the ground-water modeling task are not introduced because of the high degree of uncertainty associated with what is or is not feasible to model — on the basis of the conceptual model. For instance, an initial selection of model boundary conditions will be presented but may require modification or simplification as the modeling

task progresses because of changes in the conceptual model, and/or to overcome difficult, unforeseen complexities of the developed numerical model.

Step 9, the evaluation of the range of outcome for the final transport simulations, will allow the DOE to involve the EPA and State in the evaluation of the modeling results prior to the final documentation step.

Data are scheduled to be collected during the ecological sampling task (Section 4.5) and will be used to supplement and strengthen the reliability of some of the model input parameters. The types of data that will be used to support ground-water modeling, whether compiled and analyzed or collected, are presented in Sections 4.7.6 through 4.7.9.

Finally, an inherent assumption under the ground-water modeling task is that remediation and/or restoration of the MMTS does not result in any significant changes in the hydrologic and hydrogeologic processes at the site.

4.7.3 Conceptual Model

The overall performance and accuracy of the numerical model will depend upon the accuracy of the site conceptual model and the accuracy of estimated parameters required for model input. The following conceptual model is considered the best interpretation of data to date. Model calibration may require refinement of, and/or significant changes to, the conceptual model. Also, variations of the conceptual model will be evaluated during sensitivity analysis. The hydrologic data that have been collected on-site to date and support the hydrogeologic conceptual model of the MMTS include geologic mapping, hydrologic mapping (surface water features), stream-flow measurement data, climatic data, drill-hole lithology, ground-water occurrence (water levels), ground-water sampling and analysis results, and hydraulic characteristics data from installed monitoring wells. Other more specific data collected on the Near South Site and Far South Site also contribute to the conceptual model of the MMTS (see DOE 1993a, DOE 1994b). Section 2.4 of this document, Hydrologic Setting, discusses in detail the hydrogeology and surface water characteristics of the MMTS. Section 2.4 and documents cited therein, are the basis for the current conceptual model.

The conceptual model focuses on the overall performance of the hydrologic system at the MMTS with specific regard to flow direction, relative flow magnitude, and contaminant transport behavior. Discussion has been separated into the general topics of surface water, ground water, and contaminant transport. The ground-water section has been further divided into unsaturated flow and saturated flow. The conceptualization of the primary flow paths at the MMTS includes a partial discussion of field data and observations that support the conceptual model interpretation. Figures 4.7-1 and 4.7-2 are generalized hydrogeologic cross-sections depicting the primary flow paths and processes at the MMTS.

Finally, the general procedure for estimating a water budget for the MMTS is presented. The water budget calculation could result in modifications and refinements to the hydrologic conceptual model of the MMTS.

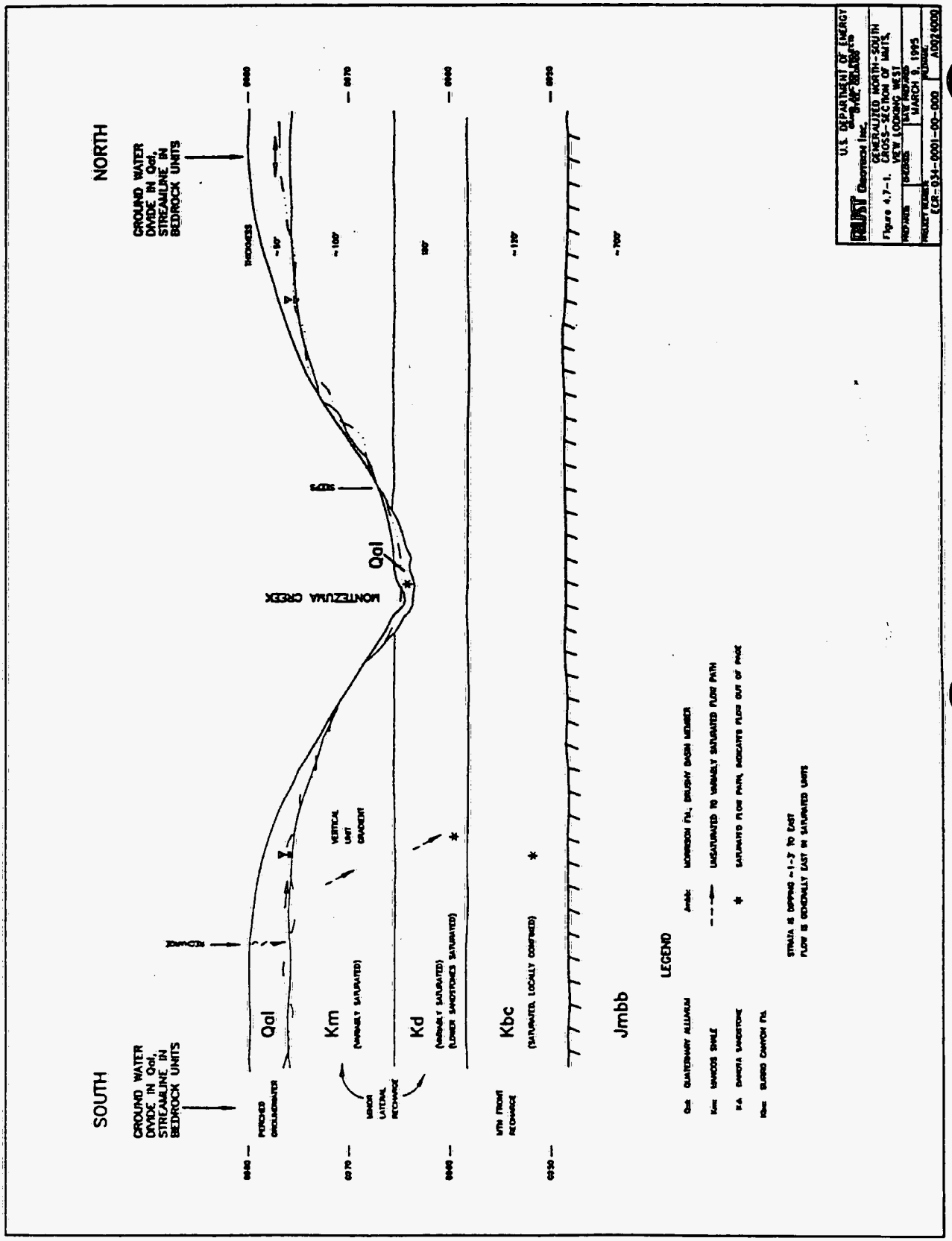


Figure 4.7-1. Generalized North-South Cross Section of MMTS, View Looking West

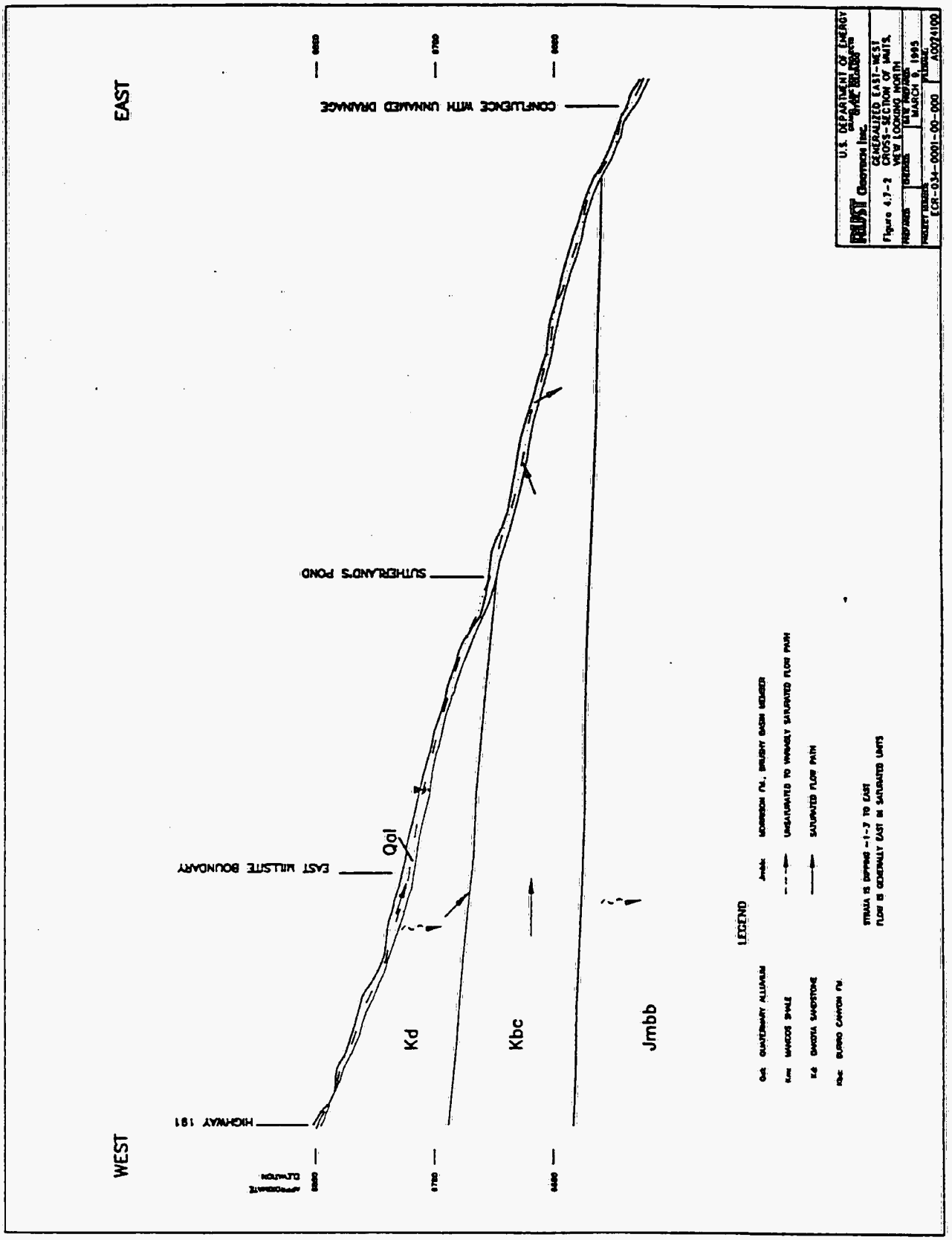


Figure 4.7-2. Generalized East-West Cross Section of MMTS, View Looking North

4.7.3.1 Surface Water Flow

The primary sources and processes of surface flow include precipitation, irrigation, runoff, infiltration of precipitation (areal recharge), evapotranspiration (ET), surface water inflow and outflow from streams, seep and spring flow, and stream-aquifer loss and gain. Although it is intended to use a net areal recharge in the numerical model, a conceptual understanding of the components of net recharge, precipitation and evapotranspiration is warranted to more fully understand conceptual flow processes.

Precipitation in the Monticello area averages almost 15 inches per year (in./yr) (Utah Climate Center 1994). Of this amount, it is estimated that from 0.25 in/yr (1×10^{-8} cm/sec) to 1.5 in/yr (1.2×10^{-7} cm/sec) infiltrates the alluvial soils as recharge. The smaller estimate is based on a soil chloride analysis from soils on the Near South Site (DOE 1994a), and the larger estimate is 10 percent of the average annual precipitation, an arbitrary approximated upper boundary. Direct recharge to exposed rock units is probably proportional to the amount of average winter precipitation (from October 1 through April 30). It has been estimated that the threshold for the initiation of recharge to exposed rock is 8 in/yr of winter precipitation (Freethey and Cordy 1991). Monticello receives approximately 8.9 in/yr of winter precipitation (Utah Climate Center 1994). This implies that recharge to surface exposures of bedrock units is minimal in the immediate vicinity of Monticello. However, at the higher elevations to the west, near and in the Abajo Mountains, recharge to exposed bedrock is expected to be greater.

Approximately 2.5 acre-feet per acre per season (30 in/yr) of irrigation water is applied to hay and alfalfa fields on the MMTS vicinity properties immediately east and north of the millsite. Dry land farming of wheat on the Near and Far South Sites probably decreases recharge to shallow ground water in these areas during the growing parts of the year and potentially increases recharge during the nongrowing season because of water ponding in furrows and eventually infiltrating instead of running off. On the basis of quoted ET rates (Andrews 1994), it is estimated that 30 to 40 in/yr of irrigation water is applied to private and public lawns in the town of Monticello.

ET in the Monticello area is estimated to be 43.8 in/yr (pan evaporation rate of 42.7 in/yr) (NRCS 1994). Consumptive use for area crops ranges from 22 to 34 in/yr depending on location (Andrews 1994). Because of these high rates, ET is expected to play a major role in the hydrological system. The lack of persistent, widespread seeps or springs in exposed Dakota Sandstone and Burro Canyon Formation indicate that ET may be an important process in removing ground water from these units in areas where the formations form ledges and cliff outcrops such as those in Montezuma Canyon.

Surface water at the MMTS consists of the generally perennial stream, Montezuma Creek, and associated in-stream ponds, several seeps and springs, Hall's Ditch, and Sutherland's Pond (Figure 2.4-2). Large surface water bodies in the vicinity of the MMTS include Loyd's Lake Reservoir, on the South Creek drainage to the west, and municipal water treatment lagoons, located north of lower Montezuma Creek.

The most consistent source to Montezuma Creek is in-stream base flow entering the site at the west boundary, near Highway 191. The amount of in-stream flow entering the site is dependent on Loyd's Lake Reservoir releases and leakage, runoff from the North Creek and South Creek watersheds (downstream from the Loyd's Lake dam), and any inflow or gain of ground water over the North and South Creek reaches. Actual dam releases seldom occur (only once, in the spring of 1993, since the dam was built in 1985). Leakage, expressed by outfall from drain pipes at the toe of the reservoir, is relatively small (a measurement in November 1994 yielded a flow of approximately 0.024 cfs [11 gpm]) at the toe of the dam. Water is diverted from Montezuma Creek into Hall's Ditch west of Highway 191. Hall's Ditch is contained in nonwatertight pipe under Highway 191 and throughout its entire reach across the northwest portion of the millsite. The ditch is open from where it exits the millsite, north of the vanadium tailings pile, to its end, approximately 0.75 mile north of the millsite. It is likely that some leakage occurs from both the piped and unlined portion of Hall's Ditch. However, the amount of ditch leakage and consequential recharge to the ground-water systems is intermittent, occurring mainly in Spring and early Summer. Also, the conveyance capacity of the ditch is estimated to be approximately 1 cfs. The potential leakage and consequential recharge to the ground water systems is therefore considered minimal in comparison of other sources of recharge. Nonetheless, the estimated recharge from Hall's Ditch will be included in the water balance estimate.

On the basis of surface stream discharge (flow) measurements, the interaction between Montezuma Creek surface water and ground water appears to be complicated (stream flow measurements were conducted during 1993 and 1994 and will continue to be conducted at least through completion of the OU III ROD). As stated in Section 2.4, only some reaches of Montezuma Creek on the MMTS seem to exhibit a consistent gain (exfluent) or loss (influent) condition. Other reaches are sometimes gaining and sometimes losing. An obvious correlation between geologic facies and stream loss or gain is not apparent. To further investigate stream-aquifer interaction, analysis is being conducted to determine the relationship among stream flow rates, ground-water levels, and precipitation events.

Conceptually, precipitation, stream flows, and ground-water levels in the upper flow system are dynamically interrelated and interconnected. For example, during high runoff periods during or after a short intense precipitation event, stream loss may be associated with stream bank storage and the escalation of ground-water levels, whereas stream gain may be associated with a subsequent storage depletion period and a decrease in ground-water levels. Both lateral and vertical flow of surface water to adjacent and underlying ground water is associated with bank storage conditions. Vertical flow or leakage from the stream channel into underlying unsaturated alluvium and/or bedrock is associated with stream loss between storm events or during base flow conditions. Montezuma Creek between stations W-4 and SW92-06 (the reach immediately downstream from the millsite) is the only reach showing a slight loss in flow (equal to or greater than 0.1 cfs and less than 1.0 cfs) during base flow conditions (October 1994). Slight gains during this same measurement period occurred between Stations SW92-02 and SW92-03, possibly from surface runoff from the North Drainage; Stations SW92-05 and W-4, possibly due to leakage from a stock/agriculture pond (located between these stations) that existed at the time; and Stations SW92-06 and Sorenson, possibly due to constriction of

the alluvial valley, discharge from the lower Dakota Sandstone and upper Burro Canyon Formation, and/or leakage from Sutherland's Pond (see Figure 3.4-2). A notable gain (approximately 1 cfs) from station SW94-01 just downstream from the Vega Creek confluence, to station "Montezuma Canyon," approximately 5 miles further downstream, occurred during this measurement period. Because of the lack of seeps and springs in the Dakota Sandstone and Burro Canyon Formation, this gain is attributed to discharge of ground water from the Brushy Basin and Saltwash members of the Morrison Formation and/or runoff from tributaries intersecting the canyon in this area.

The notable seeps and springs in the area generally occur on the hillslope north and east of the millsite. Some seepage has been observed in places on the banks of Montezuma Creek, and one major spring (Slade Spring) is located on the north bank of Montezuma Creek near the BLM compound. The Pehrson 1 and Clay Hill seeps, and Goodknight Spring, Adams Spring, and Slade Spring generally exhibit perennial flow (during year of 1994), whereas the Pehrson 2 and Upper North Drainage seeps exhibit intermittent flow. None of the seeps have developed channels; diffuse flow occurs over narrow to broad areas and is difficult to quantify. Seep flow on the north slope is apparently associated with perched ground water at the alluvium-Mancos Shale contact and/or flow emanating from the Mancos Shale itself. The interpreted origin of this ground water is natural recharge, irrigation, and potential leakage from municipal water lines. The implications of seep occurrence on the ground-water distribution in the area is discussed in the ground-water section below.

Seep occurrence on the south slope of the MMTS is comparatively small. Only scant diffuse flow from the exposed (excavated) Mancos Shale in the southeast portion of the millsite has been mapped.

The larger surface water bodies, namely Loyd's Lake, Sutherland's Pond, and the municipal water treatment lagoons, are interpreted as features of small and variable impact to flow at the MMTS. Because of the lack of monitoring wells near these features, the actual influence on ground-water levels from these features is not known. Because field observations do not indicate significant leakage from the water treatment lagoons, and no field instrumentation (wells) exists to measure the potential impact of this feature, the conceptual model assumes that any leakage from the lagoons is negligible and is not a major source to ground water in the area. However, to more fully evaluate the impact of the lagoons a water balance calculation will be conducted on the basis of available information. The small amount of leakage that occurs at the toe of Loyd's Lake Dam and Sutherland's Pond contributes to flow in South Creek and Montezuma Creek, respectively, and/or to the upper ground-water flow system upgradient of or on the MMTS.

4.7.3.2 Ground-Water Flow

The primary processes of ground-water flow within and between hydrostratigraphic units on the MMTS include unsaturated flow (infiltration of precipitation and percolation of ground water in variably saturated material), and saturated flow (lateral recharge and discharge or leakage). Stream-aquifer interaction is included in the saturated flow section.

Unsaturated Flow

Unsaturated flow occurs in the unsaturated portion of the upper flow system and in the variably saturated Mancos Shale and Dakota Sandstone where these units form the underlying bedrock at the MMTS. The occurrence of unsaturated flow is recognized in the hydrologic conceptual model. However, unsaturated flow will not be modeled explicitly on a large scale because the process is not considered vital to the model's overall performance. The saturated numerical flow model (MODFLOW) circumvents unsaturated flow, i.e., recharge is treated as a volumetric flow rate that enters the saturated zone. Similarly, evapotranspiration is treated as a volumetric flow rate that exits the saturated zone.

In the unsaturated alluvium and soil of the upper flow system, the importance of unsaturated flow lies in the role it plays in recharge and the transport of contaminants to upper flow system ground water. Recharge occurs when infiltrating precipitation and surface water enters the upper flow system. Moisture in the unsaturated zone above the root zone is susceptible to evapotranspiration, whereas moisture below the root zone can percolate downward to the phreatic surface, recharging the ground water. As previously discussed (Section 4.7.1), recharge is difficult to estimate and has been approximated. In areas where the unsaturated alluvium is thin, near the valley margins, areal recharge is expected to occur more quickly because of the smaller storage capability of the thin soils. The numerical model's implicit treatment of unsaturated flow is acceptable because the numerical simulations will represent decades of transient flow during which the average annual recharge flux through the unsaturated zone is assumed to reach equilibrium. The role unsaturated flow plays in the transport of contaminants is addressed under "Contaminant Transport."

Unsaturated conditions also exist in places in the Mancos Shale and most of the upper and middle Dakota Sandstone. Wells installed in the thin remnants of Mancos Shale on the north margin of the millsite generally have fully saturated screens whereas wells on the south margin of millsite typically have ground-water levels within the screen or sandpack interval. Water levels in monitoring wells installed in the upper and middle Dakota Sandstone are situated in or below the sandpack, indicating relatively low pressure head and partially unsaturated conditions. On the basis of drilling log information from private wells to the north of the MMTS and project (OU I) wells to the south of the MMTS, the variably saturated conditions in the Mancos Shale and Dakota Sandstone are suspected to exist over the entire local area (within several miles of the MMTS), including the entire model domain (see Section 4.7.5).

Near the margins of the valley and south of the MMTS, a vertical unit hydraulic gradient (gravity drainage) exists in the Mancos Shale and Dakota Sandstone indicating a strong downward component of ground-water flow. It is assumed that similar conditions exist on the mesa to the north of the MMTS. The variably saturated conditions and small hydraulic conductivities, however, restrict significant matrix flow from occurring. Furthermore, the distinct geochemical signatures and relative age differences between ground water of the Dakota Sandstone and the Burro Canyon aquifer also support the concept of limited hydraulic communication between these units (DOE 1994a). The small number of monitoring wells completed in the Mancos Shale and Dakota Sandstone prohibit the construction of extensive

ground-water elevation contour maps; however, the lateral gradient between upgradient Dakota well 92-13 and downgradient Dakota well 92-12 is approximately 0.008.

Saturated Flow

The MMTS and vicinity is underlain by Quaternary alluvial material which is, in turn, underlain (youngest to oldest) by Mancos Shale, Dakota Sandstone, and Burro Canyon Formation, all of Cretaceous age. The Burro Canyon Formation is underlain by the Brushy Basin Member of the Morrison Formation (Jurassic age). Most of the MMTS consists of the upper and lower Montezuma Creek valley which, from west to east, progressively incises the Mancos Shale, Dakota Sandstone, Burro Canyon Formation and Morrison Formation.

The upper flow system on the MMTS consists of the saturated portions of alluvial and colluvial deposits, and, in places, weathered bedrock. Weathered bedrock has been included in the conceptual model of the upper flow system because it is hypothesized that weathered bedrock has similar transmissive characteristics as the alluvial deposits (however, the numerical model does not include weathered bedrock in the alluvial aquifer; see Section 4.7.6.2).

Ground water in variable quantities also occurs in the Mancos Shale, Dakota Sandstone, and Burro Canyon Formation. The upper flow system is dominated by a horizontal, eastward component of flow. This flow is induced by the hydraulic conductivity (approximately 10^{-1} to 10^{-5} cm/sec) of the upper flow system over that of underlying bedrock (approximately 10^{-4} to 10^{-9} cm/s), and the eastward hydraulic gradient (0.01 to 0.04 ft/ft). The upper flow system is considered a perched ground-water system in areas where it overlies the variably saturated Mancos Shale and Dakota Sandstone on the MMTS. Variably saturated upper to middle Dakota Sandstone is subcrop throughout most of the Millsite, and is suspected to form subcrop up to 3,000 feet east of the Millsite.

No wells exist on the north slope to allow a factual shallow ground-water level contour map to be constructed. However, the seeps on the north slope represent the approximate elevation of shallow ground water in the area. The occurrence of the seeps and shallow water levels from wells on the Millsite's north boundary lead to the interpretation that shallow ground water continuously occurs in places between the thin alluvial/colluvial deposits and weathered bedrock underlying the north slope and the alluvial deposits that make up the main upper flow system of the valley floor (see Plate 4-1 and 4-2, DOE 1994b). The quantity of flow entering the MMTS from the north-northwest will be estimated in the water budget calculation.

Ground-water flow from the south slope of the MMTS is considered negligible. This interpretation is supported by the lack of seeps and saturated alluvium, as observed during field mapping and well installation work in the area. Wells on the south slope (wells 194, 195, 196, and 197-4) were completed in the Mancos Shale — the shallowest interval that indicated the presence of ground water. One of these wells is dry and the others have minor amounts of water, indicating that the shale is mostly unsaturated in the area.

On the outlying mesas north and south of the MMTS, the Quaternary alluvium varies in thickness from 0 to 70 feet or more. Saturated thicknesses also vary, from 0 to an estimated 20 feet. Ground-water flow generally mimics topography. Flow is generally eastward except where local low areas or drainages divert flow to the north or south. Because of the apparent strong relationship between topography and flow direction, alluvial (or shallow weathered bedrock) ground water distant and north and south of the MMTS is not expected to be within flow paths that intersect the MMTS. Therefore, topographic areas that appear to form, continuous hydraulic divides, or areas where the flow path is apparently due east, justifiably act as boundaries to shallow flow around the MMTS.

The main sources of recharge to the upper flow system are ground-water inflow originating west and north of the MMTS, infiltration of precipitation, irrigation, and other surface water, and leakage from Montezuma Creek. Minor recharge is also suspected as a result of underflow from the south slope of the valley (approximate gradient of 0.08 to 0.1 ft/ft).

Discharge from the upper flow system within the MMTS occurs mainly by downgradient ground-water outflow, discharge to Montezuma Creek, and evapotranspiration. Most likely, some additional discharge occurs by leakage to underlying bedrock. Where vertical gradients can be measured between the upper flow system and bedrock, values for gradients to the lower Dakota Sandstone consistently range between 0.95 and 1.0 ft/ft, while values for vertical gradients to the Burro Canyon aquifer are from 0.07 to 0.66 ft/ft. The unit vertical gradient between the upper flow system and the Dakota Sandstone indicates a good potential for vertical flow. Conceptually, however, minor vertical flow occurs because of the sharp contrast in hydraulic conductivity between the upper flow system and the Dakota Sandstone. This interpretation is further supported by the poor yield of ground water to Dakota wells. In addition, there is inconclusive geochemical evidence of contamination in the Dakota Sandstone. This, however, may be due to an ability of the Dakota Sandstone to adsorb contaminants.

As discussed above, variably saturated ground-water conditions exist in the Mancos Shale and Dakota Sandstone. These units receive some recharge from leakage of the overlying alluvium, where it is saturated. This recharge is most prevalent in the shallow weathered bedrock where fractures are more common. For practical purposes, saturated weathered bedrock is considered part of the upper flow system on the MMTS. Downward flow into deeper unweathered bedrock is restricted to areas where vertical to subvertical continuous fractures exist.

Shallow Mancos Shale is believed to be saturated on portions of the north slope of the upper Montezuma Creek valley, where seeps are common at the contact with the overlying alluvium and in the shale itself. Wells on the north boundary (202-2 and 203-2) of the Millsite also show saturated intervals of shallow Mancos Shale. Primary paths of discharge for the saturated portions of the Mancos Shale include shallow leakage to slope alluvium/colluvium, seepage from outcrop, and evapotranspiration. Secondary discharge paths include discharge to Montezuma Creek on the western portion of the MMTS and downward leakage to the Dakota Sandstone.

Although existing Dakota Sandstone wells on the MMTS have been completed in the lower part of the unit, it is conceivable that portions of the upper and middle Dakota Sandstone are fully saturated. In particular, the upper and middle Dakota Sandstone may receive some recharge from leakage of the upper flow system and/or Montezuma Creek. The fractured coal seams common to the middle Dakota Sandstone may be more conducive to this flow and do contain ground water on the Near South Site immediately south of the MMTS. However, the discontinuous nature of the coal layers and the overall low permeability of the Dakota Sandstone indicate recharge and overall flow is minimal. The origin of the lower Dakota Sandstone ground water is from vertical flow, either from slow downward percolation from overlying variably saturated strata, or from upward flow from the confined portions of the Burro Canyon aquifer. Secondary potential sources of recharge include infiltration of precipitation at outcrop and associated lateral flow into the MMTS.

The lower 5 to 15 feet of Dakota Sandstone is saturated in some wells in and around the MMTS. Although a limited number of borings have penetrated the lower Dakota Sandstone and few lower Dakota Sandstone wells exist, it is assumed that the extreme lower portion of the Dakota Sandstone is saturated within most of the entire modeling domain. This assumption serves as a conservative measure to flow and transport in this portion of the model domain and as a simplification to development of the numerical model (see Section 4.7.6.2). The lower Dakota Sandstone is assumed to be unsaturated in the area from approximately the confluence of North and South Creeks to the west edge of the model domain. This corresponds to the area where the Burro Canyon aquifer is unconfined. Because of the low-permeability and associated characteristics cited above and in Section 2.4, overall inflow and outflow in the Dakota Sandstone is considered negligible.

The Burro Canyon aquifer is unconfined approximately 2000 feet upgradient of the Millsite, where it shows water levels at least 50 feet below the top of the formation at wells 92-02 and 92-04. Confining pressures are apparent at well 92-06, immediately west of Highway 191, where water levels are approximately 11 feet above the top of the formation. The transition from unconfined to confined conditions is assumed to occur in the area near the confluence of North and South Creeks. The aquifer appears to be confined over most of the MMTS and vicinity with the greatest confining pressure (approximately 30 ft. above the top of the formation) measured at well 197-2 on the adjacent Near South Site. Well 92-10, the eastern-most Burro Canyon well, shows water levels 2 to 4 ft. above the top of the formation. However, because this well is directly overlain by alluvium, shows good seasonal variation in water levels, and levels within a few feet (below) of the adjacent alluvial well, Burro Canyon ground water is interpreted as semi-confined here. Hydraulic gradients in the Burro Canyon aquifer are approximately 0.004, 0.006, and 0.01 for areas upgradient, on, and downgradient of the millsite, respectively (DOE 1994b).

The primary source of recharge to the Burro Canyon aquifer is by way of infiltration of precipitation and runoff in exposed areas west of the MMTS near the Abajo Mountains. This flow is induced by the aquifer's permeability; approximately 10^{-4} cm/s. On the MMTS, upgradient lateral inflow is, therefore, the chief recharge process.

Some recharge and discharge of the Burro Canyon aquifer occurs where Montezuma Creek and the upper flow system directly overlie the formation in lower Montezuma Creek, between Sutherland's Pond and the Vega Creek confluence. At well cluster 92-09 and 92-10, a downward hydraulic gradient of approximately 0.07 exists from the upper flow system to the Burro Canyon aquifer. However, on the basis of base flow conditions in the fall of 1994, Montezuma Creek experiences a small gain (see Section 2.4.4) in flow over the reach underlain by the Burro Canyon Formation immediately downgradient of these wells. The gain in stream flow may be attributed to Burro Canyon aquifer discharge or discharge of the upper flow system because of further constriction of the system in Montezuma Canyon. The relatively small magnitude of the stream gain and its inconclusive source imply that other significant discharge processes for the Burro Canyon aquifer exist. Because of the lack of common seeps and springs at the downgradient cliff outcrops of the Burro Canyon Formation, ground-water discharge of the Burro Canyon aquifer apparently occurs by other means. The primary discharge flow paths for the Burro Canyon aquifer are interpreted to be discharge to Montezuma Creek and the upper flow system between approximately Sutherland's Pond and the Vega Creek confluence, evapotranspiration in the vicinity of Montezuma Canyon, minor leakage into the underlying Brushy Basin Member of the Morrison Formation, and some potential underflow into the thin alluvial veneer overlying the Brushy Basin at the base of the Burro Canyon outcrops.

Conceptually, the Brushy Basin Member of the Morrison Formation is considered relatively impermeable because of its high shale and clay composition. It is probable that the vertical matrix hydraulic conductivity of the Brushy Basin is on the order of 10^{-7} to 10^{-9} cm/s; essentially impermeable compared to the conductivity (10^{-4} cm/s) of the overlying Burro Canyon aquifer. Because of this contrast in conductivities, the Brushy Basin is considered the practical bottom of the conceptual flow model for the MMTS and vicinity. However, because of periodic gains in flow in Montezuma Creek below the Vega Creek confluence (where the stream overlies the Morrison Formation) and the apparent lack of visible, or other more obvious discharge flow paths for the Burro Canyon aquifer, some leakage may occur from the Burro Canyon aquifer to the alluvial veneer overlying the Brushy Basin Member, and/or to the Brushy Basin Member itself.

Bedrock ground-water flow is eastward (due east for the Burro Canyon aquifer) because of the eastward sloping topography and stratigraphy, but it is also influenced in areas of significant local relief. Flow paths may somewhat diverge from an eastward direction in areas such as upper and lower Montezuma Creek and Montezuma Canyon. Conceptual boundaries for flow then, can be established at some distance north and south of the MMTS, on the basis that eastward streamlines that exist there no longer influence flow within the MMTS.

4.7.3.3 Contaminant Transport

The distribution of some COPCs in ground water are illustrated in the *Baseline Characterization Data Summary* report (DOE 1994b). On the basis of this report and the

COPCs evaluated, uranium showed the greatest potential for transport, followed by molybdenum, vanadium, and arsenic. Manganese and selenium also showed a general inverse relationship between ground-water concentrations and distance from the Millsite.

After soil remediation of the MMTS, the transport behavior of these COPCs is expected to be similar, with new, reduced concentrations of the COPC being progressively established in the ground water and surface water downgradient from the millsite.

The conceptualization of contaminant transport focuses on transport processes that are expected to occur after soil remediation at the MMTS. Although not significantly different, transport processes that are occurring now (pre-remediation) are more applicable to transport calibration (Section 4.7.8.2).

After soil remediation is conducted on the MMTS, two primary unnatural sources of COPCs will potentially remain as contributors of contamination to the surface and ground water at the MMTS. These sources are 1) leachate from residually contaminated and unsaturated soils, and 2) desorption of existing contaminants within the saturated portion of the upper flow system. Currently, the potential source of contamination originating from stream sediments is considered secondary and insignificant compared to the primary sources. The existence of extensive, post-remediation residual soil contamination will be tested by conducting post-remediation sampling and analysis of site soils under OU I.

Given that some residual contamination is expected, an understanding of the unsaturated component of flow and transport within the unsaturated upper flow system is necessary to accurately model the site. In residually contaminated soils, transport is largely dependent on unsaturated ground-water flux (dependent on soil moisture, see Section 4.7.3.2), and the distribution and diffusion coefficients for the contaminant in question. Contaminated leachate will be generated when relatively clean precipitation and/or irrigation water infiltrates the soils and desorbs some of the contaminants sorbed to the soils. Leachate will continue to percolate downward until it merges with the phreatic surface of the upper flow system. The leachate then, is a source of contamination to the ground water of the upper flow system. Generally, the greater the saturation (higher moisture content) and the smaller the distribution coefficient (K_d) and diffusion coefficient, the greater the amount of contaminant will be leached to the phreatic surface.

Saturated transport of leached contaminants will begin at the phreatic surface and continue within the aquifer (upper flow system). Because of the relatively large hydraulic conductivities of the upper flow system, advection is expected to be the primary mode of transport. Minor transport will occur from diffusion. Contaminants entering the upper flow system will gradually disperse as a result of hydrodynamic dispersion. Dissolved concentrations of contaminants will also attenuate because of sorption, the partitioning of a contaminant between that adsorbed to solid material versus that in solution.

Contaminants already existing in the upper flow system are expected to gradually desorb as a result of a decrease in the overall concentrations of contaminants in the ground water (due to

the removal of the largest source term [tailings]), with or without extensive contribution of contaminated leachate. This is because tailings leachate and tailings within the saturated zone of the upper flow system will no longer contribute source contamination to the system. The decrease in the dissolved concentrations of COPCs and other elements will enhance desorption of COPCs, depending upon the particular K_d assigned for each COPC. The adsorption/ desorption process will continue to operate downgradient of the site until redistribution of contaminants has reached a new equilibrium resulting in a significant decrease in COPC concentrations in ground water and surface water.

Other chemical characteristics such as pH and Eh affect the speciation, sorption, and overall mobility of some inorganic COPCs, but typical to transport models widely used in ground-water remediation problems, tgese cgaracterustucs are not incorporated into the transport governing equations. Therefore, presenting the intricacies of a geochemical conceptual model is not within the scope of the transport modeling task.

Surface and ground-water inflows such as precipitation, seeps and springs, Montezuma Creek, and lateral underflow (ground water) will contribute contaminant mass that is equivalent to sampling and analytical results. Some of these sources will contribute background concentrations and are otherwise uncontaminated by man-introduced constituents (chemical analysis of a sample collected from Slade Spring was completed in the spring of 1995).

4.7.4 Estimation of Water Budget

The water budget will be estimated prior to numerical modeling in an attempt to quantify the primary flow components described in the conceptual model. The water budget calculation will support and allow for further development of the current conceptual model and will later give an indication of how well the numerical model represents the conceptual model. The water budget calculation will result in tabulated ranges of potential inflows and outflows for the alluvial aquifer. Examples of inflow and outflow include areal recharge, upgradient ground-water inflow, stream loss, evapotranspiration, downgradient ground-water outflow, and stream gain. Specific estimates for each component of inflow and outflow will be shown on calculation sheets. Estimates will be made on the basis of available data; for example, recharge will be estimated using average annual precipitation data, recharge relationships presented in literature, and/or field tests, and stream loss and gain will be based on field measurements of stream discharge. Upgradient and downgradient ground-water flow will be estimated using flow nets, and/or geometric averages of hydraulic conductivity, calculated hydraulic gradients, and aquifer cross-sectional areas. The estimation of vertical recharge and discharge will be made on the basis of approximated vertical hydraulic conductivities, known or estimated vertical gradients, and projected areas of flow.

4.7.5 Define Model Domain, Select Numerical Model Codes, and Procurement of Materials

4.7.5.1 Model Domain

The selection of a model domain, the area in which flow and transport is simulated, is based on understanding the conceptual site model, the limitations of numerical models, regulatory issues and concerns, and the limitations of project budget and schedule. An understanding of the conceptual site model provides the most basic justification for the model domain. The conceptual model defines the primary flow and transport pathways and therefore allows boundaries to be approximated. The limitations of numerical models include issues such as maximum allowable grid cell number and the general ability to model certain conceptual processes such as stream-aquifer interaction. Regulatory issues include the influence of ARARs, as well as any supplementary input regulatory agencies may have that impact the project scope and domain. Project budget and schedule limitations include issues such as the allowable degree of model complexity and availability of computer power.

Selection of the model domain for the MMTS was driven by the conceptual model. Initial minimum requirements were that the domain include the surface area of the upper flow system within the boundary of the MMTS (millsite and peripheral properties). After further consideration and discussion with the EPA and State, the model domain was formally limited to a one-layer, two-dimensional domain, i.e. the upper flow system. The decision to limit the model to the alluvial aquifer was made after considerable examination of the uncertainties associated with a three-dimensional model that would have otherwise included the Mancos Shale, Dakota Sandstone, and Burro Canyon aquifer. It was concluded that modeling of flow and contaminant transport to the Burro Canyon aquifer would not be an accurate predictive tool because 1) the lack of knowledge of fractures and the variably saturated nature of the strata overlying the Burro Canyon aquifer prohibits a realistic vertical hydraulic conductivity from being used in these strata; the use of any other value would be conjectural, 2) if a prediction were made, the time and location(s) at which contamination reached the Burro Canyon would not be defensible, and 3) the lack of confidence in the prediction would not support a defensible decision.

Additional considerations resulted in laterally extending the boundary of the domain away from the MMTS. These included 1) an effort to attain physical and therefore more accurate and reliable model boundaries, 2) an effort to limit model boundary condition affects, and 3) the indication that significant ground-water flow occurs on the north slope of upper Montezuma Creek. As a first approximation, model domain boundaries will be located just north of Highway 666 to the north, near or at Loyd's Lake, to the west, approximately 0.5 miles south of the MMTS, and along the trace of Vega and Montezuma Creek, to the east. The resulting model domain, shown in Figure 4.7-3, is preliminary and may be modified as modeling progresses. The boundary conditions to be assigned to the domain boundaries is discussed under "Model Conditions" in Section 4.7.6.2.

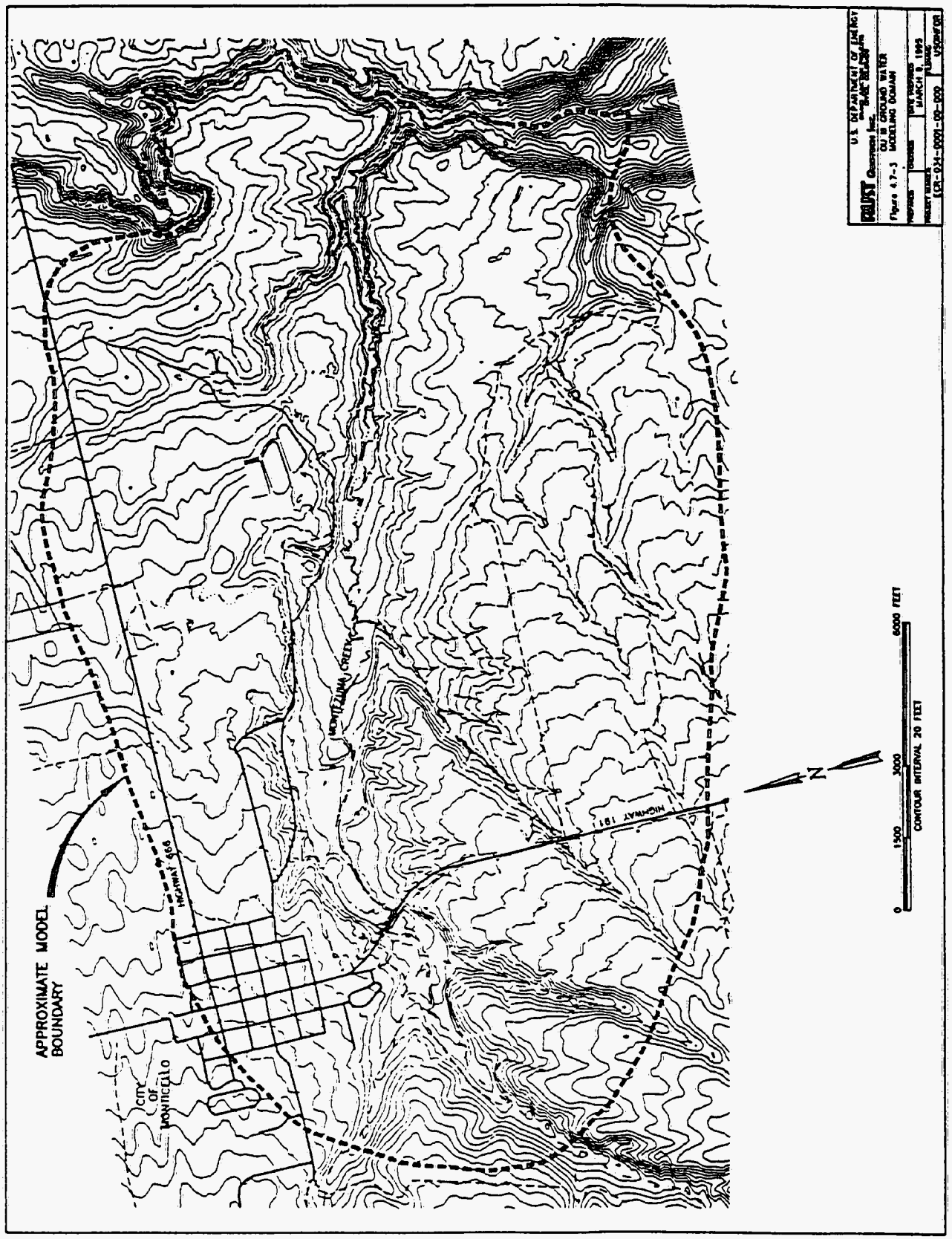


Figure 4.7-3. OU III Ground-Water Modeling Domain

Although the model is limited to a two-dimensional domain, the potential for contaminate migration into the Burro Canyon aquifer remains to be a principal concern. To address this concern, a number of new wells will be installed to more adequately monitor water quality in the Burro Canyon aquifer, and horizontal and vertical hydraulic gradients within and between hydrostratigraphic units (see Section 4.8.1). These wells will provide real-time data needed to accurately assess potential contaminant migration in the Burro Canyon aquifer now and in the future. Should contamination by COPCs be detected and confirmed in the Burro Canyon aquifer, the possible expansion of the ground-water modeling domain will be reevaluated.

4.7.5.2 Model Selection

Consideration of the modeling objectives and an evaluation of the hydrologic conceptual site model indicates that saturated ground-water flow, particularly in the upper flow system, is the primary flow process of concern at the MMTS (i.e., saturated flow and transport is the main process that moves contaminants significant distances over time). Unsaturated flow is considered a secondary process at the MMTS because characteristically this flow is less voluminous, and the unsaturated zone of the upper flow system is sufficiently thin that steady-state flow will probably result over a period of 5 years or greater, the approximate time frame of interest for the implementation of ground-water restoration. Although unsaturated flow is considered a secondary process at the MMTS, a method is needed to estimate the source term that results from the potential unsaturated flow and transport of residual (if any) contaminants remaining in the soils of the upper flow system, as well as the leaching of natural concentrations of COPCs in the native soils surrounding the MMTS. The use of a coupled unsaturated/saturated code is less preferable because of the increased complexity, intensiveness of computations, and frequent nonconverging simulations commonly experienced with these codes. To reduce the implementation problems associated with a coupled unsaturated/saturated code, unsaturated flow and transport modeling will be conducted separately, uncoupled from the saturated model, to estimate the concentrations of leachate inflow to the phreatic surface.

The three-dimensional, ground-water flow model MODFLOW (McDonald and Harbaugh 1988) will be used to simulate saturated ground-water flow on the MMTS. MODFLOW models ground-water flow using a block-centered finite difference approach. Model layers can be simulated as unconfined, confined, or a combination of these conditions. MODFLOW can simulate flow associated with wells, areal recharge, evapotranspiration, drains, and streams. The finite difference equations can be solved using the Strongly Implicit Procedure or Slice-Successive Overrelaxation (McDonald and Harbaugh 1988). HYDRUS (Kool and van Genuchten 1991), a one-dimensional flow and transport code, will be used to simulate the leaching of post-remediation soil contaminants in variably saturated soil to the ground-water surface. The solute transport equation used in HYDRUS incorporates the processes of molecular diffusion, hydrodynamic dispersion, liner or nonlinear equilibrium adsorption, and first-order decay (Kool and van Genuchten 1991). HYDRUS requires the input of van Genuchten-type unsaturated soil properties that describe the relationship between soil-moisture content and hydraulic conductivity. The results of HYDRUS will be used as input to MT3D (Zheng 1992), a two or three-dimensional saturated transport code. The concentrations of COPCs in the leachate as estimated by HYDRUS will be used as a surficial "boundary

condition" in MT3D; that is, the concentrations of COPCs will be assigned or associated with the areal recharge in the area of estimated residual contamination. MT3D will, in turn, be coupled with MODFLOW to arrive at predictions of contaminant concentrations in ground and surface water on the MMTS. MODFLOW, MT3D, and HYDRUS are modeling codes that have been tested and accepted in the ground-water modeling industry and are listed in "Compilation of Ground-Water Models" (EPA 1993e). MODFLOW, in particular, is widely used in ground-water science. MT3D is easily coupled to MODFLOW and is becoming the most common transport code used with MODFLOW. HYDRUS has gained more popularity in recent years as a relatively comprehensive variably saturated code that includes the use of characteristic unsaturated soil properties.

4.7.5.3 Procurement of Materials

Procurement of materials includes obtaining the computer hardware and software necessary to effectively implement the numerical model and the literature necessary for parameter estimation. Procurement has thus far included obtaining a Pentium computer and recent versions of the software packages VMODFLOW, GMS, and MT3D (see Section 4.7.6.2). Procurement of the computer was necessary to decrease run times associated with the potentially large size and complicated nature of the model, and to more precisely accommodate the graphic display demands of VMODFLOW and GMS. A SUN SPARC station 10 is also available to run ground-water simulations.

4.7.6 Development of Flow Model

This section discusses the development of the flow portion of the unsaturated flow and transport model HYDRUS and the development of the saturated flow model MODFLOW. Information is presented in two main subsections: Model Conditions and Parameter Estimation.

4.7.6.1 Development of Unsaturated Flow Model

Unsaturated flow occurs in the unsaturated portion of the alluvial aquifer. The primary importance of unsaturated flow is the role it plays in transporting COPCs that remain in native soils of the alluvial system after remediation, regardless whether or not these contaminants represent background concentrations. The concentrations of COPCs in leachate as estimated by the model HYDRUS will be used as a surficial "boundary condition" in the model MT3D. The concentrations of COPCs will be assigned or associated with the areal recharge in the areas of estimated residual contamination. The development of the unsaturated transport portion of HYDRUS is discussed in Section 4.7.8.1. Site specific data that contribute to the development of the unsaturated flow model include soil bulk density data, soil moisture data, sieve analysis data, and areal recharge data.

Model Conditions

Model development for the unsaturated model involves selecting the model domain, discretization of the one-dimensional grid, and selecting initial conditions and boundary conditions.

Domain

The unsaturated model HYDRUS models one-dimensional flow and transport and therefore cannot be directly coupled to a two-dimensional saturated flow model. Instead, the results of the one-dimensional unsaturated flow (and transport) will be applied to the surface "boundary" of MODFLOW. Several HYDRUS simulations will be conducted on the basis of anticipated different thicknesses of the post-remediation soil, soil types, and soil contamination levels. Zones will be established where these different conditions exist within the MMTS and individual HYDRUS simulation results will be applied to each zone.

Grid Development

The unsaturated thickness of the post-remediation soil profile is expected to vary from several feet to 15 or 20 feet. It is anticipated that the one-dimensional grid for HYDRUS will be discretized into cells that do not exceed 1 foot in thickness. However, because the performance of unsaturated flow models is generally enhanced by small discretizations, cells may be assigned thicknesses as small as one tenth of a foot in places.

Initial Conditions

When a transport simulation is performed, HYDRUS first solves the steady-state flow solution and calculates the appropriate water content distribution and velocity field that is the result of the specified boundary conditions. This information is used in subsequent transient transport simulations. The specified initial pressure head or soil moisture distribution should be a reasonable approximation to the steady-state distribution to ensure convergence of the flow equation (Kool and van Genuchten 1991).

Initial soil moisture content conditions will be generated by conducting a steady-state simulation using the boundary conditions discussed below. As a qualitative measure, moisture content data from the 1991 Millsite Characterization Study (Dames and Moore 1992) will be compared to the simulated steady-state profile.

Boundary Conditions

The anticipated boundary conditions for HYDRUS include a specified flow surface boundary (on the basis of estimated areal recharge) and a specified head lower boundary (pressure head equal to zero or water table condition). The recharge rate to be applied to the top boundary of the model is discussed in the parameter estimation section.

Parameter Estimation

Input parameters include areal recharge rate, soil bulk density, and soil hydraulic properties (which describe the relationship between hydraulic conductivity and pressure). Root water uptake and hysteresis will not be modeled. Evapotranspiration will not be modeled explicitly, but will be incorporated into a net recharge term.

Estimates of areal recharge on the basis of site specific data include previous environmental tracer work, field lysimeter work, and modeling conducted for MRAP. Preliminary estimates of areal recharge range from approximately 2×10^{-8} cm/s (0.25 in/yr) to approximately one tenth of the average annual precipitation or 1.5 in/yr (see Section 4.7.3.1). Site specific data in this case refers to estimates of recharge by the chloride mass balance method as conducted on the Near South Site (see DOE 1994a), and by monolithic lysimeters and modeling conducted on the Far South Site (Waugh 1995 and DOE 1993a). In addition, an examination of site precipitation versus water level data, literature recharge values, or published regional data on the relationships between precipitation versus elevation and/or evapotranspiration, will be evaluated.

The value of soil bulk densities is dependent on soil type. Estimates of soil bulk density for native alluvial material will be obtained from natural moisture content and dry weight density data from soil samples collected from test pits on the MMTS (Dames and Moore 1992). Bulk density values are also available for loess and/or pediment gravel soil types (DOE 1993a) which cover the nearby mesa tops and may be used as fill during restoration of the MMTS.

Soil hydraulic properties will be estimated for fill (types yet to be determined) and upper flow system materials. These properties include saturated hydraulic conductivity, and the four van Genuchten-type parameters (van Genuchten 1978), α, β, θ_r, and θ_s, that are derived from retention curve data (also known as moisture characteristic curve). The retention curve is a plotted relationship between pressure and soil moisture content. The van Genuchten parameters describe the relationship between hydraulic conductivity and pressure.

The van Genuchten parameters will be estimated by either (1) an indirect method using existing grain-size distribution data and/or additional grain-size distribution data from soil samples collected during the ecologic risk assessment sampling combined with computer analysis using the programs SWRDAT (Baumer and Brasher 1982; Baumer 1985) and RETC (van Genuchten et al. 1991); or (2) direct laboratory analysis of soil samples collected during the ecologic risk assessment sampling or installation of the proposed monitoring wells (if schedule allows). SWRDAT was developed to approximate unsaturated properties of agricultural soils. The code requires as input the grain-size distribution data of the material of interest. Grain-size distribution data for the upper flow system material exists in the 1991 Millsite Characterization Study (Dames and Moore 1992). Additional grain-size distribution data will be obtained from sieve analyses conducted on samples collected during risk assessment sampling. The program also requires an estimate of the saturated hydraulic conductivity. Because individual soil samples cannot confidently be assigned a hydraulic conductivity associated with a previously conducted and potentially distant in situ hydraulic

test, and the parameters of interest are being obtained through computer analysis of grain-size distribution data, the hydraulic conductivity will be estimated using the computer program MVASKF (Vukovic and Soro 1992). MVASKF estimates conductivity on the basis of the effective grain size (and grain size distribution) of the material. However, MVASKF does not accurately predict conductivities of cohesive, fine-grained material. Therefore, for fine-grained soil samples, the assigned saturated hydraulic conductivity value will be obtained from slug tests that were conducted in similar material on the MMTS or estimated from general literature approximations.

SWRDAT output consists of a pressure versus moisture content relationship for a hypothetical soil that is characterized by a specific grain-size distribution and saturated hydraulic conductivity. The SWRDAT output is used as input to the RETC code that estimates the relationship between hydraulic conductivity and moisture content, resulting in the van Genuchten soil properties. In addition, the unsaturated soil properties obtained from SWRDAT and RETC computations will be compared to literature values for similar materials, including estimates made from soil data provided in *A Catalogue of the Hydraulic Properties of Unsaturated Soils* (Mualem 1976).

To evaluate saturated hydraulic conductivity over a more extensive area of the model domain, approximations of conductivity based on grain-size distributions will be investigated for soil samples obtained in lower Montezuma Creek during the 1994 confirmatory sampling event. At a minimum, however, the geometric means, plus or minus an order of magnitude, of the saturated hydraulic conductivity values of the upper flow system materials (alluvium) will be obtained from previously conducted pumping tests and slug tests (see Section 2.4) and used as input to HYDRUS.

4.7.6.2 Development of Saturated Flow Model

In the two-dimensional model domain, saturated flow occurs in the alluvial aquifer. Saturated flow and advective transport are viewed as the primary ground-water flow and transport processes responsible for dispersing COPCs within this hydrostratigraphic unit on and in the vicinity of the MMTS.

The hydrogeologic conceptual model includes weathered bedrock in the definition of the upper flow system because it is hypothesized that weathered bedrock has similar transmissive characteristics as the alluvial deposits. However, project historical data show that the delineation of weathered bedrock is inconsistent at best. Also, the definition of weathered bedrock is somewhat subjective, and, where explicitly delineated it is relatively thin (0 to 3 ft). Therefore, for the numerical modeling, the upper flow system model layer will be defined by alluvial material only; weathered bedrock will not be included.

Site specific data that will be used to develop the saturated flow model include ground-water elevation data, surface water discharge data, and hydraulic conductivity, transmissivity, porosity, specific yield, and areal recharge data. These data are discussed in the appropriate subsections, Model Conditions or Parameter Estimation. However, because ground-water

elevation data and surface water discharge data represent important and extensive sources of information with several uses in the modeling process, they are discussed separately below.

Ground-Water and Surface Water Data

The most fundamental data needed to continually evaluate the conceptual model and develop and calibrate the numerical flow model includes ground-water elevation data and surface water discharge data. Consistent and reliable sources of this data exist as a result of work conducted for the baseline characterization. A description of this data and plans for continuing its collection are discussed in the following paragraphs.

Ground-Water Elevation Data

Ground-water monitoring data that is needed for development of the saturated flow model includes water-level measurement data from selected wells upgradient, on, and downgradient of the millsite. Water-level measurements will also be conducted at selected wells on the Near South Site.

Monitoring results will provide a continuous record of ground-water conditions and will be used to support ground-water modeling and contaminant fate and transport assessments and to serve as the basis for evaluating changes in the ground-water system before, during, and after tailings source remediation.

Water-level measurement data will be used to calculate flow gradients and directions, estimate water balances for the area, record and understand historic water-level fluctuations with time, understand ground-water/surface water relationships, and understand vertical and horizontal flow relationships between hydrostratigraphic units. The data will also be used to develop a dynamic average steady-state condition for flow model calibration. Hydraulic head in wells on the Near South Site will be measured to assess continuity of shallow ground water off the millsite to the south. Depending on the occurrence of ground water in this area, this information will be used to estimate shallow ground-water flux into the millsite from the south, a quantity potentially needed for the FS.

Wells were selected for water-level measurement on the basis of the following criteria: (1) maintaining the water-level measurement network developed for the baseline characterization, (2) supplementing the MMTS network with wells installed in 1993 and new wells to be installed under this Work Plan, and (3) providing water-level information peripheral to the MMTS. Wells in the baseline characterization water-level network were judged to have good spatial distribution, a high degree of integrity, and are considered to have suitable well-screen completion intervals (DOE 1994b). Maintaining the baseline characterization water-level measurement network will provide a consistent historical record of water-level fluctuations. This record will be used to evaluate how ground-water occurrence and conditions vary with time. Fluctuating water levels, for example, may impact some land use applications and/or ground-water use. Water level information from wells installed on the MMTS in 1993 as part of the Alternatives Analysis project is needed to investigate vertical

hydraulic gradients and define conditions on the perimeter of the millsite boundary. Water level information from the proposed new wells (see Section 4.8.1) will be used to evaluate local horizontal and vertical hydraulic gradients within and between hydrostratigraphic units. Ground-water level information peripheral to the MMTS includes wells on the Near South Site and one Burro Canyon well (93-205) north-northeast of the millsite. These wells lie within the modeling domain and will be used to assess local ground-water conditions and flow directions, including flow to the MMTS that may affect the water budget estimate.

A private well survey was conducted in 1994 in an attempt to obtain additional water-level information north of the MMTS. Of 30 private owners contacted, only 5 owners volunteered to have water-level measurements taken at their wells. The results of these measurements are of limited use because of the high uncertainty of relating water levels to well screen locations (as a result of poor drill log information) and the overall sparsity of measurements. Other information gained from the private well survey noted that both private individuals and public (City of Monticello) owners of deep wells (lower Dakota Sandstone, Burro Canyon) do not operate them often. Some wells have remained dormant for 10 years or more, depending on spells of drought. A representative of the City of Monticello stated that as the city's population grows, the demand for municipal water will be met by acquiring other surface water rights rather than supplementing demand with a major pumping operation (Schafer 1994).

Section 4.8.3 describes the ground-water level measurement procedures and lists the selected wells.

Surface Water Discharge Data

Surface water discharge monitoring consists of conducting stream discharge (flow) measurements, and seep and spring discharge measurements where feasible. Most seeps and springs are not amenable to measurement of discharge and are therefore monitored for general flow characteristics (see Section 4.8.5) Surface water sites currently include those stations established during the baseline characterization on Montezuma Creek upgradient, on, and downgradient of the millsite, and three new sites, SW94-01 (in Montezuma Creek downstream of the Vega Creek confluence with Vega Creek), SW94-02 (on the west portion of the millsite), and SW95-01 (in Vega Creek above the confluence with Montezuma Creek); four surface drainage sites on the millsite; and five seeps on the north hillslope, north of the millsite, and the Cabin Spring in the lower canyon area (see Plate 2-2). Any other significant seeps and/or springs identified during the course of fieldwork (annual monitoring) will be added to the monitoring list.

Surface water monitoring (initiated during the baseline characterization) will continue to maintain and record surface water discharge measurement data. Maintenance of this data is needed to evaluate short and long term historical trends and to attempt to define data norms and anomalies. An understanding of the interaction between surface water and ground water is basic to developing a ground-water numerical flow (and transport) model.

Stream discharge information will be used to characterize flow magnitude and fluctuation in upper Montezuma Canyon, assess locations and approximate rates of loss (influent) and gain (effluent) on stream reaches, assess the relationship between water quality and stream flow, calculate a water budget as a check on numerical modeling performance, evaluate surface water contaminant mass flux, and support characterization of other tasks such as the ecological assessment and/or the FS. Time-averaged stream discharge values will be used for flow calibration of the numerical model. Discharge measurements estimated at nonstream sites (seeps, springs, and outfalls) are also needed to assess the origin and quantity of flow potentially contributing to Montezuma Creek and the upper flow system. Where seep and spring discharge measurements are feasible, or can be reasonably approximated, the data will be used for the calibration of flux during the flow model calibration task.

Specific sites and procedures for the surface water discharge measurement task are discussed in Section 4.8.2.2.

Model Conditions

The development of the saturated flow model involves translating the site conceptual model information into computer input files necessary to initiate simulations. To increase the efficiency of this time-consuming task, the computer programs Visual MODFLOW (VMODFLOW, Waterloo Hydrogeologic Inc. 1994) and/or Groundwater Modeling System (GMS, Brigham Young University 1995) will be used. These programs automatically construct the required MODFLOW input files by using an interactive program that allows the user to designate a domain, design a model grid, and input layers, material properties, boundary conditions and other necessary information. Once VMODFLOW or GMS has generated the input files, the MODFLOW simulation can be run internally (with VMODFLOW) or externally (with GMS), and results can be displayed and graphically manipulated (post-processed).

The version of MODFLOW used in VMODFLOW and GMS incorporate the recent packages Block Centered Flow (BCF3), Generalized Finite-Difference Formulation (GFD1) and the Preconditioned Conjugate Gradient Solver (PCG2). The Streamflow Routing Package (STR1) will be included in a later version of VMODFLOW and is not considered necessary for the relatively small and constant flows of Montezuma Creek.

Domain size, grid development, initial conditions, boundary conditions, parameter input values, and MODFLOW model packages to be used will be evaluated as modeling progresses, and modified, if necessary, to best accommodate the needs of OU III RI/FS objectives. Modifications could range from minor parameter refinements to the construction of an entire new grid. EPA approval will be obtained prior to implementing any significant modifications. The following model development attributes are anticipated.

Domain

MODFLOW requires the construction of an orthogonal grid over the model domain. Within the orthogonal grid, however, cells that lie between the actual model boundaries and perimeter of the grid are made inactive; flow calculations are not performed in these cells. The actual model boundary, designated by specified head or flow conditions, will coincide with known or estimated physical boundaries in some locations, resulting in an irregularly shaped model domain. The northern and southern boundaries are expected to be located on ground-water flow lines and/or ground-water divides, near Highway 666 and approximately 1 to 0.5 miles south of the MMTS, respectively. The western boundary is expected to be located at Loyd's Lake, and the eastern boundary, at or just east of Montezuma Creek Canyon. These boundary locations were selected because they provide physical justifications for specifying head and flux conditions, and/or are distant from the main area of interest. A preliminary plan-view of the model domain is shown in Figure 4.7-3.

One layer will be modeled in the vertical dimension. The single layer will consist of the unconsolidated alluvial and colluvial material that make up the upper flow system of the MMTS, and the alluvium, colluvium, and loess materials that make up the surrounding highlands. As stated at the beginning of this section, weathered bedrock will not be included in this layer. Because the horizontal gradient in the alluvial aquifer appears to be dominant on the MMTS, and the unit is relatively thin (less than 40 ft thick), the model layer will not be discretized into additional layers. The bottom of the model domain will be bedrock, which varies from the Mancos Shale to Dakota Sandstone to Burro Canyon Formation, depending on location. This contact will be assigned a no-flow boundary condition. The no-flow condition is reasonable considering that the hydraulic conductivities of the bedrock generally range up to three or four orders of magnitude smaller than of the upper flow system (see also Section 4.7.5.1).

The model domain for MT3D, although generally the same as that for MODFLOW, will be reduced to the areal extent of the alluvial aquifer. This will allow for greater computational efficiency and reduced run-times of computer simulations.

Grid Development

Generally, grid construction will involve a smaller, more dense grid spacing in the area of upper and lower Montezuma Creek, on and downgradient of the millsite where contaminant transport is expected to be significant. The smaller grid-cell size will result in more precise resolution of head and contaminant concentration and general model performance. The resolution necessary will be determined partially by the needs of the human and ecological risk assessment and the FS. A larger grid spacing is expected in the areas peripheral to the MMTS. In general, grid cells are not expected to be smaller than 50 by 100 ft, and not larger than 400 by 400 ft.

Initial Conditions

Initial conditions for the MODFLOW transient simulations will consist of a steady-state head solution generated by the calibrated model. The dynamic average steady-state condition will be established by using an average annual recharge and calibrating to within the range of plus or minus one standard deviation of the average annual head at each calibration well. The initial steady-state simulation will be started using an arbitrary, yet reasonable, head distribution. Average annual recharge will be estimated as discussed in Section 4.7.3. Average annual heads will be generated, at a minimum, for wells that make up the established ground-water level measurement network (Section 4.8.1.2). Reliable and consistent water level measurements have been conducted on this network over the period of 1992 to the present. Because of diverse climatic conditions within this short period of record, water level elevations will be averaged over time for the entire period (January 1992 to January 1995, for example) rather than for a given year within the period. Wells not on the network will be considered for averaging depending on the well integrity, quality assurance of measurements, and frequency and period at which measurements were made. The treatment of anomalous measurements will be examined on a case-by-case basis.

Boundary Conditions

The north and south boundaries of the model are expected to be no-flow conditions because the boundaries are located on ground-water flow lines or ground-water divides. On the western boundary, the impact of the potential constant head condition at Loyd's Lake on the alluvial aquifer does not initially appear to be significant, however, it will be further evaluated. The resulting boundary condition in this area may be revised from no-flow to a specified head boundary. Boundary conditions for the remaining portions of the west boundary, north and south of Loyd's Lake, may also be revised from specified head to no-flow. The eastern boundary conditions may range from specified head or an internal source condition such as evapotranspiration or a drain-type boundary, or a combination of these conditions, depending on the final boundary location. Figure 4.7-3 indicates that the east boundary is located along Vega and Montezuma Creeks. In this case, a specified head boundary, drain-type condition, or no-flow may be appropriate.

The east boundary condition is expected to become more clear after the water budget calculation is conducted.

Other than during sensitivity analysis, the assignment of a quantified specified flow boundary condition will be avoided because of the increased amount of uncertainty associated with these type of boundaries as compared to specified head boundaries.

Internal Sources and Sinks

Internal sources include areas where stream reaches and seeps or springs are located. The River Package in MODFLOW will be used to simulate the exchange of water between Montezuma Creek and the upper flow system. In MODFLOW, the stream acts as a source

where it contributes flow to the aquifer and as a sink when it receives flow from ground-water sources. If necessary, the River Package may also be applied to seepage from Hall's Ditch. The Drain Package will be used to simulate flow from the defined seeps and springs, and the Evapotranspiration and/or Drain Packages may be used to simulate evapotranspiration in areas where the process may be a dominant sink, such as along the walls of Montezuma Canyon, north and south of the Vega Creek confluence.

Parameter Estimation

The primary parameters required for MODFLOW input include hydraulic conductivity, transmissivity, porosity, specific yield, and areal recharge. Sources of existing data that will support parameter estimation for the saturated flow modeling include, but are not limited to:

- Hydraulic conductivity estimates for the upper flow system from unpublished pumping test data from two tests conducted on the MMTS in 1988, and unpublished slug test data from tests conducted on the MMTS in 1993 and 1994. Forty-six slug tests were conducted on the MMTS in 1994 to supplement information that supports the site conceptual model and numerical model. Additional hydraulic conductivity values will be estimated from slug tests that will be conducted at the new alluvial monitoring wells to be installed under this Work Plan (see Section 4.8.1). Also, the potential exists for obtaining supplemental hydraulic conductivity information for the millsite area associated with OU I plans to pump and supply contaminated ground water to be used for testing the water treatment plant. Should the opportunity arise, a pumping test will be designed and implemented with the condition of using existing wells. Because this work is uncertain, however, no formal plans for conducting a pumping test are described in this Work Plan. As a first approximation, geometric means of the pumping test and slug test hydraulic conductivity data will be used for the upper flow system. A realistic range of conductivity values will be used during calibration.

- Transmissivity for the upper flow system from pumping tests conducted in 1988 on the MMTS. MODFLOW accepts the input of transmissivity directly or calculates transmissivity on the basis of input hydraulic conductivity and aquifer saturated thickness values.

- The thickness of the alluvial aquifer (model layer) will be estimated by subtracting a contoured bottom elevation map from a contoured top elevation map. The top elevation contour map will be constructed using actual ground surface elevation data from the monitoring wells and surface survey control points, and/or additional estimated elevations in areas where no surface control exists. Bottom elevations for the alluvial aquifer will be estimated by contouring the elevation of the top of bedrock on the basis of similar field data. Each grid cell in the model will be assigned an interpolated alluvial thickness on the basis of the resulting thickness contour map. Alternatively, should a variable bottom elevation create excessive simulation problems, an average bottom elevation may be assigned to each layer.

- Porosity, and specific yield estimates for the upper flow system will be obtained from previous hydraulic testing data (a reevaluation of unpublished data and data presented in *RI/FS-EA* [DOE 1990b]), laboratory data (Advanced Terra Testing 1992) and literature, e.g., Bedrock Aquifers of Eastern San Juan County, Utah (Avery 1986).

- Areal recharge estimates will be based on values estimated for the Far South Site (DOE 1993a), the Near South Site (DOE 1994a), literature, and/or some percentage of total average annual precipitation.

4.7.7 Initial Flow Simulations, Calibration, and Sensitivity Analysis

4.7.7.1 Initial Flow Simulations

Initial flow simulations for both the unsaturated and saturated models will be conducted to test for general model performance and reasonable output. This subtask will serve as a test for the compatibility of the established conditions indicated by the conceptual model and the numerical flow model's ability to perform under those conditions. The goal of the initial simulations is to achieve 1) a successful run, 2) a run that does not have cells go dry as a result of artificial oscillations in the solution, 3) convergence, 4) less than 1 percent water budget error, and 5) an array of starting heads that are solved heads. During initial flow simulations, "bugs" that are preventing successful simulations will be identified and corrected. Should initial conceptual representations or conditions repeatedly result in model nonconvergence or excessive run times, alternate simplified conditions may be implemented until successful, representative model simulations are attained. Initial runs will be followed by flow calibration.

4.7.7.2 Flow Calibration

No formal calibration will be conducted for the unsaturated flow model HYDRUS. However, soil moisture contents simulated by the model will be compared for a reasonable fit to moisture contents measured on site during the 1991 Millsite Characterization Study (Dames and Moore 1992).

For the MODFLOW model, calibration will generally consist of calibrating to a dynamic average steady-state condition by using manual trial and error adjustments of input parameters. The dynamic average steady-state condition will be established by varying an average annual recharge and/or hydraulic conductivity values for the alluvial aquifer and calibrating to within the range of plus or minus one standard deviation of the average annual head at each calibration well. Average annual head will be estimated by calculating time-averaged water levels for each well in the ground-water level measurement network (Section 4.8.1.2) over the greatest period of record that contains full annual cycles, for example, from January 1992 to January 1995.

Calibration will be considered complete once predetermined calibration criteria are met. If calibration criteria cannot be met because of schedule constraints, the best possible calibration

will be attained in the time available. Calibration criteria will be set in terms of aquifer head residuals (difference between simulated head and closest standard deviation range value) meeting a minimum root mean square error (RMSE) value, and surface water flows that attain a reasonable comparison to field measured values. In addition, further refinement of calibration may be achieved by interpolating simulated heads at actual well locations by using a triangulation calculation with the simulated heads at node locations. A preliminary target RMSE for head calibration is 3 ft. Because of error associated with 1) head that will be calibrated against time-averaged values (transient conditions not reflected in the model), 2) grid cell sizes that do not reflect small scale heterogeneities, 3) potential scaling effects due to long well screens, 4) interpolation problems between actual well locations and grid nodes, and 5) field measurements (Anderson and Woessner 1992), it is uncertain whether this calibration target can be met.

Calibration will focus on the head distribution within the MMTS for the upper flow system. Approximately 30 upper flow system wells will be selected for calibration on the MMTS. The 30 upper flow system wells will be selected from those shown in Table 4.8-3, Proposed Ground-Water-Level Measurement Network for OU III. Head residuals will be quantitatively presented.

With respect to calibration of flux, field measured and time-averaged stream flows for stream reaches within the MMTS will be compared to stream fluxes for the corresponding groups of river package grid cells in the MODFLOW model. The time-averaged stream flows will be derived over the same period as that for ground-water elevations. Because stream flows are more volatile than ground-water levels, the averaged field data may be more difficult to calibrate. Therefore, the calibration criteria for stream flows will be to attain fluxes that are reasonably comparable (approximately within a factor of $\pm$ 1.5) to field measured flows. Among other parameters, stream bottom (river) conductance will be adjusted to achieve the best calibration possible. The occurrence and relative magnitude of flow from seeps and springs as simulated by MODFLOW's Drain Package will also be evaluated as part of the flow calibration. Quantitative seep flux calibration criteria are not possible because field measurements from most seeps are not feasible. Again, the calibration criteria for seep and spring flows will be to attain fluxes that appear reasonable. Reasonable flux rates from most seeps (see Figure 2.4-2 for locations) is in the range of approximately 5 to 25 gallons per minute.

If reasonable calibration does not appear attainable, the conceptual model will be reevaluated and the numerical model modified, if necessary. This may include minor changes in boundary conditions or major changes in grid design.

4.7.7.3 Flow Sensitivity Analysis

A sensitivity analysis of both the unsaturated model HYDRUS and the saturated model MODFLOW will be conducted.

The flow sensitivity analysis for HYDRUS will include varying boundary and initial conditions (surface flow and initial pressure or water contents) and the main soil hydraulic properties (van Genuchten parameters) that determine unsaturated hydraulic conductivity. Model outcome will be documented with respect to these variations. The range of variation for each parameter or group of parameters tested in the sensitivity analysis will be based on perceived maximum and minimum values on the basis of widely different soil types, and/or two standard deviations above and below the mean as obtained from site data or literature research.

Flow sensitivity analysis for MODFLOW will consist of a methodical series of simulations that test the effect of changes in the values of certain input parameters on the head distribution and flux conditions of the calibrated simulation. The sensitivity analysis will help quantify the uncertainty of the calibrated model caused by the uncertainty in the input parameters (Anderson and Woessner 1992). Parameters such as boundary conditions, hydraulic conductivity, and recharge will be varied, one at a time, within realistic ranges, and simulations will be conducted and compared to the calibrated simulation. The results of the sensitivity analysis will be presented quantitatively, for example, by tabulating resulting RMSE's and/or residual head distributions.

4.7.8 Development of Transport Model

This section discusses the development of the transport portion of the unsaturated flow and transport model HYDRUS and the development of the saturated transport model MT3D (coupled to MODFLOW). Information is presented in two main categories: model conditions, such as boundary conditions, initial conditions and grid design, and parameter estimation.

4.7.8.1 Development of Unsaturated Transport Model

The results of the unsaturated flow and transport model HYDRUS will provide a source term or transport boundary condition that exists at the phreatic surface of the upper flow system as input into MT3D. Depending on the site-wide distribution of COPCs in soil, HYDRUS will be used to generate zones of source term values for a particular COPC over the millsite and other portions of the MMTS. The concentration of contaminants in leachate from areal recharge that takes place on the mesa tops north and south of the MMTS but within the model domain, will be approximated in a range from zero (insignificant) to a HYDRUS calculated value on the basis of the concentration of contaminants within soil samples collected from the Reference Study Area. A minimum of three COPCs will be modeled by HYDRUS.

Model Conditions

Model domain size and grid development are developed under the flow model and are generally inherited by the transport model. The following model development characteristics are anticipated.

Initial Conditions

The initial COPC soil contamination data input to HYDRUS will originate from soil chemical analytical data from the 1991 Millsite Characterization Study (Dames and Moore 1992), the 1994 confirmatory sampling effort, and the planned 1995 soil sampling associated with the Reference Study Area and risk assessment task (Section 4.5). These analytical data are considered conservative because they are obtained by digesting a pulverized soil sample with acid which results in a total analyte concentration. In addition, it is assumed that the additional mass of contaminant in soil moisture is adsorbed to the soil. Smaller analyte concentrations are expected from the less rigorous natural leaching process (infiltration of precipitation) that actually occurs.

In addition, because limited soil analyte concentration versus depth data exists, the maximum thickness of the contaminated soil profile will conservatively be equal to the anticipated thickness of the remaining native soils (not including fill added during site restoration).

Boundary Conditions

Potential boundary contaminant fluxes involve 1) downward contaminant flux associated with areal recharge, and 2) upward contaminant flux through the lower boundary associated with contaminants in the ground water at the phreatic surface. Contaminant flux associated with areal recharge is relatively small compared to ground-water concentrations and will be considered negligible (assigned a value of zero). The migration of contaminants from ground water at the phreatic surface may initially be important in cases where initial capillary flow is substantial in relatively clean soil. However, because HYDRUS actually solves for the concentration at the lower boundary, it is assumed that soil concentrations of COPCs are the dominant source of contamination.

Parameter Estimation

The primary transport parameters for the unsaturated model HYDRUS include K_d, dispersivity, and decay constants.

The estimation of the distribution coefficient K_d, will be obtained primarily from literature research. Literature research will focus on obtaining estimates of K_d for the COPCs of interest for similar soils (alluvium). Two additional investigations will be conducted to evaluate implied "field" K_d values on the basis of existing soil and ground-water analytical data. The first investigation will examine data from the only two monitoring wells (91-03 and 91-14) where both soil samples and ground water have been analyzed, and the second investigation will involve conducting a simplified mixing calculation on the basis of tailings lysimeter analytical data (source term) and ground-water analytical data downgradient of the millsite. These investigations should reveal the relative amount of retardation certain COPCs (a minimum of three) are experiencing within the upper flow system. Finally, laboratory K_d (R_d) data that is the result of work performed for MRAP OU I and the Alternatives Analysis project will be evaluated for applicability to OU III modeling. Unless otherwise indicated by

literature research and the laboratory data, adsorption will occur as described by a linear isotherm (Freundlich coefficient equals one).

Dispersivity will be estimated on the basis of literature research. Research has shown that dispersivity is scale and time dependent. The parameter has been estimated for transport problems ranging in scale from laboratory column tests to actual field sites with migrating contaminant plumes. For the case of applying HYDRUS to variably saturated transport in the unsaturated portions of the upper flow system, dispersivity (longitudinal) is not expected to exceed approximately one third the expected overall distance of contaminant migration (the thickness of the unsaturated zone).

Decay constants required for input to HYDRUS include coefficients for both the dissolved phase and adsorbed phase. With the exception of radioactive COPCs, many of the COPCs are inorganic elements that are relatively recalcitrant or non-decaying; therefore, the decay coefficients will be considered negligible. Decay coefficients for radioactive COPCs will be conservatively set at zero because of the generally long half-lives associated with these elements relative to an approximate time frame of ground-water restoration.

4.7.8.2 Development of Saturated Transport Model

The development of the transport model MT3D (Zheng 1992), in part, parallels flow model development. MT3D is a modular three-dimensional transport model. The model is designed to be used with any block-centered finite element flow model such as MODFLOW. MT3D is based on the assumption that changes in the concentration field will not measurably affect the flow field. MT3D uses a mixed Eulerian-Lagrangian approach to solve the three-dimensional advective-dispersive-reactive equation. The chemical reactions included in the model are linear or nonlinear sorption and first-order irreversible decay or biodegradation (Zheng 1992). The version of MT3D used will accommodate the packages included in VMODFLOW and/or GMS.

Site specific data that will be used to develop the saturated transport model includes ground-water and surface water sampling and analysis data. Because these data represent important and extensive sources of information with multiple uses in the modeling process, they are discussed separately below.

Ground-Water and Surface Water Data

The most fundamental data needed to continually evaluate the conceptual transport model and develop and calibrate the numerical transport model includes ground-water and surface water sampling and analysis data. Consistent and reliable sources of these data exist as a result of work conducted for the baseline characterization. A description of these data and plans for continuing data collection are discussed in the following paragraphs.

Ground-Water Sampling and Analysis

Analytical data are needed to delineate and monitor contaminant migration or occurrence within the alluvial aquifer. Analytical data will contribute to the evaluation of source term location and concentration, retardation, hydraulic dispersion, and overall contaminant mobility. The data will be used in the numerical modeling task to develop a dynamic average steady-state condition for transport calibration and for initial condition and boundary condition input. The data will later be used to confirm the predicted effectiveness of remediation and/or to verify overall model performance. Finally, ground-water analytical data will be used in conjunction with analytical data from other media to determine the COPCs on the basis of risk to human health and the environment.

Wells were selected for sampling and analysis on the basis of two criteria (1) maintaining the sampling and analysis network developed for the baseline characterization, (2) the inclusion of two wells installed in 1993 (well 201-2, an upper system well, located in the north portion of the millsite and apparently in an area near a potential source, and well 205, a Burro Canyon well, located approximately 1,500 feet northeast of the millsite), and the inclusion of eight new wells proposed in this Work Plan (Section 4.8.1). Maintaining the baseline characterization sampling and analysis network will provide a consistent historical record of contaminant concentrations in ground water for OU III. These wells are judged to have good spatial distribution and well integrity and are considered to have suitable well screen completion intervals (DOE 1994b). Ground-water quality monitoring and the analytical program are described in Section 4.8.1.1 and 4.8.3, respectively.

Surface Water Sampling and Analysis

Surface water sampling and analysis will be conducted at 13 Montezuma Creek stations, 1 Vega Creek station, 2 seeps, 1 spring, and 1 outfall on the millsite (see Plate 2-2), to assess the degree of contamination within surface water and its relationship with flow magnitude, surrounding ground-water quality, and surrounding soil contamination. Surface water monitoring results will serve as a basis to evaluate changes in the surface water system before, during, and after source remediation, and will also be used to determine the COPCs on the basis of the risk assessment.

During the OU III RI/FS Project, surface water sites in the sampling and analysis network will be periodically reviewed. Sampling sites will be added to or subtracted from the network to accommodate specific changes in project needs or issues. Section 4.8.2.1 describes the details of surface water quality monitoring task.

Model Conditions

In the MT3D model, sources of contamination are assigned as solute concentrations, that is, concentrations dissolved in water. Therefore, contamination sorbed or otherwise mineralogically attached to soils and sediments cannot be designated as source. Source concentrations sorbed to solid material can only be indirectly assigned by initially specifying

ground-water concentrations and a K_d. The model will then simulate adsorption and desorption of contaminants on the basis of an assumed equilibrium between water concentrations and solid concentrations as controlled by K_d. MT3D does not apply adsorption isotherms to stream water and stream sediment. Therefore, contaminant mass lost to surface water will be removed entirely from the transport simulation. With the exception of evapotranspiration where mass flux is considered zero, the concentration of sinks is generally not specified and are considered the concentration of ground water in the aquifer.

The development of the transport model will focus on identifying sources and sinks of contamination on the MMTS and translating them to initial conditions, boundary conditions, and internal sources and sinks.

Sources or sinks of contamination external to the model are assigned at model boundaries. Boundaries to the model that allow flow will be assigned a specified contaminant concentration depending on their location. These sources or sinks are described under boundary conditions and include the influx of contaminants at the surface due to migration of leachate in the unsaturated zone, and the influx of upgradient or background contamination. Sources or sinks of contaminant flux internal to the model include Montezuma Creek and identified seeps and springs. The source term for Montezuma Creek is described under initial conditions, and seeps and springs are discussed under internal sources and sinks.

Model domain size and grid development are developed under the flow model and are inherited by the transport model. To increase the efficiency of the MT3D transport simulations, however, the domain will be reduced to the actual domain over which transport is expected to occur, i.e. the Montezuma Creek alluvial canyon. The following model development characteristics are anticipated.

Initial Conditions

Initial conditions will be established for both the transient transport calibration step and the final transient simulations. To initiate transport calibration, initial concentrations of COPCs in the entire reach of Montezuma Creek within the MMTS will be represented by concentrations as measured and averaged at current upgradient stream stations. This assumes that current upgradient concentrations are representative of concentrations in all of Montezuma Creek prior to operation of the millsite. Similarly, ground-water concentrations of COPCs in the entire upper flow system will be represented by concentrations in wells upgradient of the millsite.

Similar to the flow model, the initial conditions for MT3D transient simulations will be represented by the results of transport calibration. Transport calibration (see below) will attempt to reproduce dynamic steady-state average concentrations in ground water and surface water. The dynamic average steady-state ground water and surface water COPCs concentrations will be obtained by averaging the quarterly and semi-annual laboratory analytical data from samples collected from the established network of sampling wells and surface water stations for the period of record (November 1992 to November 1995). Anomalous measurements will be evaluated on a case-by-case basis. Average concentrations

for a minimum of three COPCs will be assigned for each reach of Montezuma Creek, as defined by the established surface water stations and for wells in the upper flow system that are part of the sampling and analysis network.

The importance of establishing the dynamic average steady-state concentrations as initial conditions for the final transient simulations becomes apparent when approaching the problem of desorption of contaminants in aquifer sediments. Stream-bottom sediment sorption is not modeled in MT3D. Once initial conditions are established for contaminants in ground water, corresponding concentrations are "assigned" to the solid phase by MT3D, depending on the adsorption/desorption equilibrium as controlled by K_d. Transient simulations will then begin with a given amount of contaminant sorbed to the solid phase, as determined by initial ground-water concentrations.

Boundary Conditions

Selecting boundary conditions for the transport model MT3D involves assigning COPCs concentrations to surface and ground-water sources in the modeled domain, including surficial sources (recharge or leachate concentrations). COPCs in ground-water in-flow at the upgradient western boundary will initially be assigned time-averaged concentrations. For the alluvial aquifer, the average concentrations will be based on laboratory analytical data from samples collected at upgradient wells (wells 92-01 and 92-03). Because these wells are located east of the west model boundary, between Highway 191 and Loyd's Lake, it is assumed that ground-water concentrations of COPCs in these wells are approximately equal to concentrations that are actually at the boundary, approximately 2,000 feet to the west. After remediation, the concentration of COPCs in leachate from infiltrating precipitation may vary with time. The boundary condition input to MT3D will reflect the relationship between leachate concentration influx and time, as determined by the unsaturated modeling (HYDRUS).

Internal Sources and Sinks

Sources or sinks of contaminant flux internal to the model include Montezuma Creek and identified seeps and springs. Montezuma Creek will be considered an internal line source for initial conditions only (see above). Once a transient simulation is initiated, Montezuma Creek will act as a line source to the aquifer in areas where the stream is losing. The stream acts as a line sink for contaminants in areas where the stream is gaining. Once contaminants in ground water enter the stream, they are no longer available for contribution to the aquifer at a downstream reach of the stream. The model does not take into account mixing with the stream and will not calculate the COPC concentrations in surface water in Montezuma Creek for any given point or time.

Defining Montezuma Creek as a line source/sink can be viewed as having both conservative and nonconservative characteristics. It is possible, for example, that in later time in transient simulations, the stream will act as the only source of contamination to the aquifer in places. This situation will add more contaminants to the ground water than conceptually expected. In

other instances, the removal of mass by way of the creek, never to be allowed to reenter the aquifer again, is a nonconservative process. The transfer of contaminant mass between the stream and aquifer will be monitored as modeling progresses. If necessary, modifications to the model will be made, if possible, to more realistically simulate contaminant interchange between the aquifer and stream.

To arrive at an estimate of stream COPC concentrations at a particular location, the relationship between contaminant concentrations in Montezuma Creek and adjacent ground-water concentrations will be analyzed. Should this analysis reveal a strong positive correlation (similar concentration magnitudes and trends), ground-water concentrations may be used to approximate stream concentrations. If there appears to be a poor correlation between ground-water concentrations and stream concentrations, stream concentrations will be estimated for specific locations using a computer algorithm that will calculate concentrations on the basis of a mixing equation and MODFLOW/MT3D river cell output.

Sampling and analysis data from seep and spring sources will be used to determine if significant quantities of COPCs are contributing to Montezuma Creek and the upper flow system. If it is judged that significant seep flow and therefore contaminant flux is contributing to the ground water and surface water of the MMTS, the respective seep or spring will be assigned a specified concentration on the basis of sampling and analysis data. Depending on remediation activities, it is anticipated that Slade Spring, the largest spring identified on the MMTS, will be modeled as a point source of flow and contamination to Montezuma Creek. Modeling the other seeps as point sources of contamination is not likely because of the small or diffuse and undiscernible amount of flow characteristic to these seeps.

Parameter Estimation

The primary transport parameters needed for MT3D include K_d and dispersivity. Existing sources of data that will support parameter estimation for the transport modeling include, but are not limited to:

- K_d estimates for the alluvial aquifer. These will initially be estimated from literature, previously conducted laboratory work for the Alternatives Analysis Project (DOE 1994a) and Far South Site work for OU I (DOE 1993a), and from an examination of soil and ground-water analytical data as described in the K_d discussion in Section 4.7.8.1.

- Dispersivity (longitudinal and transverse) for the alluvial aquifer. These will initially be estimated from literature on the basis of scale of the distribution of contaminants at the MMTS.

Final values of both K_d and dispersivity will be obtained through transport calibration.

4.7.9 Initial Transport Simulations, Calibration, and Sensitivity Analysis

4.7.9.1 Initial Transport Simulations

Initial transport simulations for both HYDRUS and MODFLOW/MT3D will be conducted to test for general model performance and reasonable output. This subtask will serve as a test for the compatibility of the established conditions indicated by the conceptual model and the numerical model's ability to perform under those conditions. During this time, "bugs" that are preventing successful simulations will be identified and corrected. Should initial conceptual representations or conditions repeatedly result in model nonconvergence or excessive run times, alternate simplified conditions may be implemented until successful, representative model simulations are attained. Initial runs will be followed by transport calibration.

4.7.9.2 Transport Calibration

The goal of transport calibration is to lend additional confidence to overall model performance. Although the reproduction of existing contaminant plumes using plausible input parameters would indicate that this goal has been met, caution should be used in associating a high degree of certainty or confidence in subsequent model simulations or predictions. Reasons for this are that the advection-dispersion equation solved by the transport model is an approximation of the theory of contaminant transport, and a calibrated solution is not a unique solution. Furthermore, the flow model itself is only a model and cannot be expected to fully replicate all the flow characteristics of hydrogeologic system.

No transport calibration of the HYDRUS model will be conducted. This model is being used to estimate source term concentrations using one-dimensional calculations; no specific field or laboratory data exist to support transport calibration of this model. However, regarding overall model performance, several verification and validation problems are presented in the HYDRUS manual (Kool and van Genuchten 1991).

Calibration of the MODFLOW/MT3D transport model will involve conducting manual trial and error transient simulations in an effort to reproduce three dynamic-averaged COPC concentration distributions in the ground water of the upper flow system. Each dynamically averaged concentration distribution will represent an average concentration for that COPC for the period identical to that used to calculate a dynamic average steady-state head distribution (as used in flow calibration). The transient transport calibration simulations will be initiated using dynamic average steady-state flow conditions and averaged ground-water and surface water COPC concentrations. The upgradient baseline concentrations of COPCs, although relatively small compared to millsite area concentrations, will be evaluated and may be input as initial upgradient source term concentrations. The primary input parameters that will be varied during calibration are, source term initial conditions, distribution coefficient, and dispersivity. It is expected that dispersivity will be derived during the calibration process.

Because contaminant distributions in ground-water (as illustrated in the Baseline Characterization Data Summary report ([DOE 1994b]) indicate that tailings on the millsite are

the primary source on the MMTS, average source term influx concentrations will initially be estimated for source areas on the millsite only. Should the primary calibration effort indicate that secondary sources are needed downgradient of the millsite, then soil sampling and analysis data from the confirmatory and risk assessment sampling will be used to estimate source term(s) in this area.

Data that will contribute to source term estimation for the millsite are tailings pile lysimeter analytical data, and ground-water analytical data from wells screened within saturated tailings or in saturated alluvium immediately below tailings. The lysimeter data consists of one sampling event of 5 lysimeters that were installed on the four tailings piles on the millsite in 1991. It is expected that the lysimeter data will be used in two ways. First, data that was collected in lysimeters immediately above the phreatic surface will be used directly as source term concentrations. Second, data that was collected from lysimeters some distance above the phreatic surface will be input into the HYDRUS model to estimate leachate concentrations for source term. Lysimeter samples collected approximately 10 ft or greater above the phreatic surface may warrant modeling with HYDRUS as the capillary fringe zone is not expected to exceed this height. The ground-water analytical data is from wells sampled as part of the established baseline characterization network. If necessary, the HYDRUS model will be used to approximate source term in downgradient areas using the same approach described under Section 4.7.8.1.

Calibration will be considered complete after the following transport calibration criteria are met: (1) demonstrate reasonably comparable reproductions of the dynamic average concentration distributions for three COPCs in ground water on the MMTS, and/or (2) for each well for which baseline analytical data exist, achieve simulated concentrations that lie within plus or minus two standard deviations of the mean concentration for the well. The relevancy of the second criteria takes into account the relative percent difference (RPD) that exists for field duplicate data for different ranges in concentrations. Therefore, any simulated concentration that falls inside the plus or minus two standard deviation range will be considered calibrated and there will be no associated residual concentration. However, for cases where the simulated concentration falls outside of the plus or minus two standard deviation range, a RMSE will be calculated. The RMSE will be calculated on the basis of the sum of the differences between the concentration at the plus or minus two standard deviation bound and the simulated concentration (that falls outside of the plus or minus two standard deviation range). The RMSE will allow an overall assessment of calibration quality. The second criteria will only be conducted if project schedule allows.

This calibration approach was selected because of the large range in observed COPC concentrations over the MMTS, and the inherent variation and uncertainty associated with the complex task of sampling and analysis. Other complications that contribute to transport calibration error include the following: (1) concentrations will be calibrated against time-averaged values (transient conditions not reflected in the model), (2) grid cell sizes that do not reflect small scale heterogeneities, (3) variabilities in well screen length (i.e., depth-averaged

concentrations), (4) interpolation problems between actual well locations and grid nodes, and (5) problems associated with field and analytical measurements (Anderson and Woessner 1992).

4.7.9.3 Transport Sensitivity Analysis

The transport sensitivity analysis for HYDRUS will include varying boundary and initial conditions (surface contaminant flux and initial soil contaminant concentrations) and the soil hydraulic properties (van Genuchten parameters) that control the value of the unsaturated hydraulic conductivity. Model outcome will be documented with respect to these variations. The effect of different boundary conditions will be examined by assigning a contaminant flux at the surface boundary, representing hypothetical precipitation contaminant concentrations. The lower boundary will not be varied as it is not typically assigned concentrations. The range of variation for soil contaminant concentrations will be based on field measured maximum and minimum values and/or two standard deviations above and below the mean. The soil hydraulic properties will be varied collectively, representing a wide range in soil types, as conducted in the flow sensitivity analysis.

Transport sensitivity analysis for MODFLOW/MT3D will consist of a series of simulations that test the effect and uncertainty of various input parameters on model output. Parameters such as initial source-term concentrations, boundary condition concentrations, distribution coefficient, and dispersivity will be varied within realistic ranges, and simulations will be conducted and compared. In addition, flow model parameters such as hydraulic conductivity and areal recharge will be varied to illustrate uncertainty effects on transport results. The secondary modeling objective to predict exposure point concentrations based on varying source terms for select metals (remaining at the millsite after remediation) will be accomplished under the transport sensitivity analysis task. Initial source-term concentrations will be varied within ranges determined by HYDRUS results. Ranges of concentrations of select metals in soils remaining on the millsite will be calculated from existing data for native soils samples collected from boreholes on the millsite (Dames and Moore 1992). An anticipated procedure will be to obtain summary statistics from this analytical data and conduct simulations using factors of the standard deviation as potential maximum and minimum limits to source term concentrations.

It is assumed that the transport sensitivity analysis will have similar results for any COPC used; therefore, only the COPC with the greatest apparent mobility will be assessed for sensitivity analysis. The results of the sensitivity analysis will be quantitatively presented by tabulating resulting RMSEs.

4.7.10 Conduct and Evaluate Final Transport Simulations

The final transient transport simulations will consist of runs where the best estimated values of input parameters are used (those used to achieve flow and transport calibration), in addition to specific input concerns related to risk assessment and/or the performance and feasibility of a passive remediation technique.

Transient flow and transport simulations for post-remediation scenarios will be initially conducted for the periods of 10, 25, and 70 years for three COPCs. These initial simulations will satisfy the first objective (see objectives in Section 4.7.1), to predict future exposure point concentrations of select COPCs in surface water and ground water. COPC concentration contour plots for each simulation will be presented. If necessary (see Internal Sources and Sinks, this section), average surface water concentrations of COPCs will be calculated for specific locations on the basis of MODFLOW and MT3D individual grid cell flux data. In grid cells where the stream is gaining, the rate of this gain and the average ground-water COPC concentration as predicted by the models will be used in a mixing calculation with the approximated volume and COPC concentration in surface water in the corresponding stream reach. In reaches where the stream is losing, the concentration will be approximated on the basis of the assigned average initial condition concentration in the reach and/or the approximated concentration in the upstream reach.

Subsequent simulations will be conducted until the second objective is satisfied. Specific simulations will be conducted and refined to within plus or minus 5 years of the time required for exposure point concentrations of the selected COPCs in surface water and ground water to dilute by hydrodynamic dispersion to levels that are protective of human health and the environment and meet the other reference criteria (MCLs, ARARs, background concentrations, risk-based concentrations, and other TBC criteria). Again, concentration contour plots will be presented. The secondary objective to predict exposure point concentrations based on varying source terms for select metals remaining at the millsite after remediation will be satisfied under the transport sensitivity analysis task (see above). The secondary objective that concerns support and/or potential confirmation of the hydrogeologic conceptual model will be realized in calibration efforts. Finally, the secondary objective of predicting exposure point concentrations for select COPCs in surface water and ground water for response action alternatives pertains to applying the model to potential alternatives defined in the FS.

Upon completing the final flow and transport simulations, the DOE will evaluate the range of possible outcomes. Results of these simulations will be made available to the EPA and State for review and comment prior to the documentation of modeling results.

4.7.11 Documentation of Results

Documentation of the ground-water modeling results will be incorporated into the RI report and follow a format similar to this Work Plan. Brief descriptions will be made of subtasks such as establishing boundary conditions, designing the model grid, and defining sources and sinks. Documentation of tasks such as model calibration and sensitivity analysis will partially rely on a graphical and tabulated presentation of results. The final flow and transport transient simulations will similarly be graphically presented by individual COPCs within a specific transient simulation time (e.g., 25 years).

4.8 Task 7: Annual Monitoring

An annual monitoring program for surface water and ground water was initiated in 1992 (DOE 1992d) and will continue as the Annual Monitoring Task at least through completion of the OU III Proposed Plan and ROD for these media. Annual Monitoring Task activities include collection of ground-water and surface water samples for chemical analysis, monitoring surface water discharge at locations within and peripheral to Montezuma Creek, and monitoring ground-water levels in the primary hydrostratigraphic units of the study area.

The ground-water and surface water monitoring activities implemented under the Annual Monitoring Task will directly support the Ecological Risk Assessment, Human Health Risk Assessment, and Ground-Water Modeling Tasks identified previously in this document. With the exception of the installation of new monitoring wells proposed under this Work Plan, the rationale and design for each Annual Monitoring Task activity, as well as the intended use of the data obtained, are developed fully in the study designs of Sections 4.5 and 4.6.

4.8.1 Well Installation

Eight new wells are to be installed cross- and downgradient of the millsite to monitor water quality and hydraulic gradients in the alluvial aquifer, Dakota Sandstone, and Burro Canyon aquifer. However, one of the eight wells, well 92-05, will only be installed if a nearby existing well, well P92-04, cannot be sufficiently developed for water-quality monitoring. The well locations are shown on Plate 2-2.

Two (potentially three) alluvial monitoring wells will be installed in the alluvial valley downgradient of the millsite. These wells will be used to help assess the extent of COPC contamination in the alluvial aquifer. Two of these wells, 95-01 and 95-03, will be installed downgradient of the existing eastern-most (or downgradient-most) alluvial well, well 92-09; they will be paired with Burro Canyon wells 95-02 and 95-04, respectively. The remaining well, well 95-05 will be installed only if existing alluvial well P92-04 cannot be adequately developed to yield suitable water for sampling purposes. Well 95-05 would be installed approximately 2300 ft east of the millsite on the northern margin of the valley. Assessment of ground-water quality at this location will help delineate extent of contamination in the northern portion of the alluvial aquifer. All of the proposed alluvial wells will be paired with new Burro Canyon wells to assess vertical hydraulic gradients between the alluvial aquifer and the underlying bedrock unit (at well site 95-05 Dakota Sandstone exists between the alluvium and Burro Canyon aquifer). Finally, the new alluvial wells will also be used to evaluate horizontal hydraulic gradients within the alluvial aquifer.

On the basis of existing well data, it is anticipated that the encountered alluvial material will be thin, between approximately 10 and 20 ft. As a result, well screens will probably be no greater than 10 ft long. Well casing diameters will be 2 inches. The alluvial wells will be installed using air rotary or hollow stem drilling methods, and all borings will be logged for lithology on the basis of split-barrel samples obtained during drilling.

Four of the wells, 95-02, 95-04, 95-06, and 95-08 will be installed in the Burro Canyon aquifer downgradient of the millsite. Once installed, these wells, in conjunction with existing Burro Canyon wells, will form a critical well network that will be used to monitor water quality in the Burro Canyon aquifer. The real-time analytical data collected from these wells will provide the basis for assessing the potential migration of COPC contamination to the Burro Canyon aquifer. Collectively, all of the Burro Canyon wells will also be used to assess the horizontal hydraulic gradients within the Burro Canyon aquifer and where paired with alluvial wells, to assess vertical hydraulic gradients.

Burro Canyon wells 95-02 and 95-04 are to be located in the eastern portion of Upper Montezuma Creek on and paired with alluvial wells 95-01 and 95-03, respectively. The main purpose of these wells is to monitor water quality in the Burro Canyon aquifer in an area that is 1) a significant distance downgradient or east of the existing eastern-most Burro Canyon well 92-10, and 2) where the Burro Canyon Formation subcrops directly underneath the alluvial aquifer. Burro Canyon well 95-06, located on the northern margin of the alluvial valley between the millsite and well 92-10, and Burro Canyon well 95-08, located on the highlands just west of the municipal waste water lagoons, have been located in these northern positions to assess potential downgradient and due east migration of contamination from the millsite. Well 95-06 will also be paired with an alluvial well, either a new well, 95-05, or existing well P92-04, if this well can be developed adequately to yield suitable water for sampling.

Burro Canyon wells will be completed within the upper portion of the Burro Canyon Formation. It is anticipated that screened intervals will extend from 10 to 20 ft below the top of the aquifer. The wells will be 4-inch diameter wells, completed using air rotary methods and designed to prevent aquifer cross-contamination during and after installation. Borings will be cored through bedrock intercepts and logged for lithology.

The remaining well, well 95-07, is to be installed in the Dakota Sandstone, several hundred feet north of the east end of the millsite. The purpose of this well is to monitor water quality in the Dakota Sandstone at a location between the millsite and the City of Monticello. Water quality data from this well will provide the information needed to assess the potential migration of contaminated ground water from the millsite area to the north. Water level data collected from the well will be used to assess horizontal hydraulic gradients in the Dakota Sandstone in the area of the millsite.

The well will be completed in the first encountered ground water that exists below the projected alluvial aquifer water table elevation that exists on the millsite. Because the Dakota Sandstone is variably saturated and of low permeability in this area (see Section 2.4), the detection of small amounts of ground water may be difficult. Therefore, drilling will be conducted using particular care and effort to detect small zones that bear ground water. For example, any suspected or detected increase in moisture either observed in core, drill cuttings or vapor, or detectable change in drilling behavior will be noted. Such occurrences will be evaluated, and if necessary, drilling will stop and the boring will be tested for the presence of ground water. Once ground water is encountered or strongly indicated, a 5-ft long, 2-inch diameter well screen will be installed in the water bearing interval, using conventional installation methods. The Dakota Sandstone well will be drilled using air rotary methods and designed to prevent aquifer cross-contamination during

and after installation. The boring will be cored through the bedrock intercept and logged for lithology. If no water-bearing intervals are encountered between the top of the Dakota Sandstone and the Burro Canyon Formation, the borehole will be abandoned.

All wells will be designed using specifications (e.g. screen slot size), that have been successfully used in previous drilling and well installation work for OU III.

Ground-water monitoring schedules for the new wells are discussed in the following sections.

4.8.2 Ground Water Quality Monitoring

Ground-water sample collection and laboratory analysis will be conducted to monitor contaminant concentrations and distribution and geochemical parameters, within the hydrostratigraphic units of the study area. A detailed description of the site hydrostratigraphy is in Section 2.4 of this document.

Ground-Water Sampling Locations

Ground-water samples will be obtained from 36 ground-water monitoring wells for laboratory analysis under the Annual Monitoring Task. Table 4.8-1 summarizes the ground-water sampling wells according to well location relative to the millsite and water bearing formation. The locations of the ground-water quality sampling wells are shown in Plate 2-2.

As indicated in Table 4.8-1, the upper-flow system will be sampled at 22 well locations, including 3 wells located hydraulically upgradient of the millsite, 8 wells located on the millsite, and 11 wells downgradient of the millsite. The Burro Canyon aquifer will be sampled at 10 well locations, including 3 upgradient wells, 1 millsite well, 1 cross-gradient well, and 5 down-gradient wells. The lower Dakota Sandstone formation will be sampled at 3 well locations, including 1 upgradient, 1 cross-gradient, and 1 downgradient location. The remaining sampling well is completed in an interval of saturated lower Dakota Sandstone and the upper Burro Canyon aquifer and is located downgradient of the millsite.

With the exceptions of wells P92-02, P92-04, P92-09, 36SE93-201-2, 31NE93-205, and wells 95-01 through 95-08 (Table 4.8-1), the Annual Monitoring Task will utilize the wells which comprised the ground-water sampling and analysis network of the Baseline Characterization. Wells P92-02, P92-04, and P92-05 were installed as piezometers during Baseline Characterization. Although these wells were originally installed to measure water levels, their construction is similar to all other upper flow system monitoring wells, therefore, following development of these wells, samples collected from these locations will be representative of the water quality at each location. If well P92-04 does not develop sufficiently to become suitable for sampling, then a third upper flow system well (95-05) will be installed (see following paragraphs).

Wells 36SE93-201-2 and 31NE93-205 were installed during the Alternatives Analysis Project (DOE 1994b), and were subsequently added to the OU III annual monitoring

Table 4.8-1. Proposed Ground-Water Sampling Locations

Upper Flow System Sampling Wells			
Upgradient	**Millsite**		**Downgradient**
92-01 92-03 92-05	82-30B 82-40A 82-42 82-31B-E	31SW91-03 31SW91-14 31SW91-23 36SE93-201-2	82-07 88-85 92-07 92-08 92-09 92-11 P92-02 P92-04 (or 95-05[a]) P92-09 P95-01[a] P95-03[a]
Burro Canyon Aquifer Sampling Wells			
Upgradient	**Millsite**	**Cross-gradient**	**Downgradient**
92-02 92-04 92-06	93-01	31NE93-205	92-10 95-02[a] 95-04[a] 95-06[a] 95-08[a]
Lower Dakota Sandstone Sampling Wells			
Upgradient	**Millsite**	**Cross-gradient**	**Downgradient**
92-13	N/A	95-07[a]	92-12
Lower Dakota/Upper Burro Canyon Sampling Well			
Upgradient	**Millsite**		**Downgradient**
N/A	N/A		83-70

[a]Proposed new well identification; wells to be installed October/November 1995.

network. Shallow ground water was encountered during installation of well 36NE93-201-2, extending the previously estimated boundary of the upper flow system. The well was appended to the network due to relatively high concentrations of uranium and vanadium

detected in samples collected during the April 1994 sampling round and confirmed by the October 1994 sampling results. The analytical results imply the existence of a potential contaminant source area (previously unidentified) at or upgradient of this location.

Well 31NE93-205 was installed in November 1993 approximately 1,500 ft northeast of the millsite and is completed in the Burro Canyon aquifer. It was first sampled in April 1994. The well will continue to be sampled as a cross-gradient well to monitor background water quality in the Burro Canyon aquifer immediately north of the millsite.

Wells 95-02, 95-04, 95-06, and 95-08 are proposed downgradient Burro Canyon wells; wells 95-01, 95-03, and 95-05 are proposed downgradient upper flow system wells; and well 95-07 is a proposed cross-gradient lower Dakota Sandstone well. These proposed wells are scheduled to be installed during October and November 1995.

Other modifications to the original Baseline Characterization sampling and analysis network include reconstruction of well 84-77 (renamed 93-01) and substitution of well 31SW91-03 for well 82-36A prior to the October 1993 sampling round. During the OU III RI/FS project, the sampling and analysis network will periodically be reviewed and wells may be added to or subtracted from the network to accommodate specific changes in project needs or issues.

Sampling Frequency: Inorganic Analytes

Ground-water sample collection under the Annual Monitoring Task will occur semiannually, except for wells installed during October and November 1995 and wells P92-02, P92-04, and P92-09. At these wells, sampling will occur approximately quarterly for the first year of sampling and then semiannually after the first year coinciding with the other semiannual sampling rounds. All samples will be analyzed for the inorganic parameters listed in Table 4.8-2, with the exception of nitrite, noted in the following paragraph. The semiannual rounds will coincide with periods of typical high seasonal water levels (April) and low seasonal water levels (October), as inferred from previous investigations and historical records (refer to Sections 2.0, 3.0, and 4.7 of this document). Each sampling round is anticipated to begin approximately mid-month. The semiannual ground-water sampling rounds will proceed concurrently with the surface water sampling program described in Section 4.8.3 of this document.

Nitrite (Table 4.8-2) will only be analyzed in samples from well 31SW91-23. DOE-GJPO, DOE-HQ, EPA Region VIII, and State of Utah concurrence to reduce sampling and analysis for nitrite to this single location was achieved prior to the October 1993 semiannual sampling round. Since the initiation of the annual monitoring program in 1992, results indicate that nitrite concentrations have not been increasing in samples from this location. If future results indicate increasing nitrite concentrations at this location, additional downgradient monitoring wells will be considered for nitrite analysis in subsequent sampling rounds.

Ground water parameters that will be measured in the field include alkalinity, temperature, pH, electrical conductivity, dissolved oxygen (DO), Eh, and turbidity.

Sampling Frequency: Organic Compound Analytes

On the basis of the results of the Baseline Characterization, DOE-GJPO, DOE-HQ, EPA Region VIII, and State of Utah concurrence to conduct annual sampling for the organic compounds listed in Table 4.8-2 in five upper flow system wells was achieved prior to the October 1993 sampling round.

Sampling for organic analytes at the five upper flow system wells is anticipated to occur during the April semiannual sampling rounds. The proposed sampling locations include well 92-05 (upgradient well), well 88-85 (immediately downgradient of the millsite), and three upper flow system wells located on the millsite. The three millsite wells will be selected from the current sampling network to provide a wide geographic distribution of organic compound monitoring. A different set of millsite wells will be selected for organic compound sampling and analysis for each successive annual round.

4.8.3 Ground Water Level Monitoring

Ground-Water-Level Monitoring Locations

Ground water levels will be measured in a total of 99 monitoring wells. Table 4.8-3 summarizes the ground-water-level monitoring network according to the formation in which the well is completed. The locations of the ground-water level monitoring wells are shown in Plate 2-2. As indicated in Table 4.8-3, the monitoring well network consists of 72 wells completed in the upper ground-water flow system, 23 wells completed in bedrock, and 4 wells completed in the shallow zone of the Near South Site (NSS). Several of the 1993 NSS shallow zone wells and millsite wells were completed at the intercept of first ground water. Completion intervals include alluvium, weathered Mancos Shale, unweathered Mancos Shale, or a combination of these strata, depending on location. On the MMTS, these first-water wells are classified as upper flow system wells if the screen interval is within weathered bedrock. If the screen interval is below weathered bedrock, the wells are classified as bedrock wells.

Table 4.8-3. Proposed Ground-Water-Level Measurement Network for OU III

Location	Well Number				
Upper Flow System (upgradient, millsite, and downgradient)	82-07	31SW91-03	31SW91-28	31SW91-55	92-11
	82-08	31SW91-04	31SW91-33	31SW91-56	P92-01
	82-09	31SW91-07	31SW91-34	36SE91-58	P92-02
	82-15	31SW91-08	31SW91-35	36SE91-61	P92-03
	82-20	31SW91-09	31SW91-36	36SE91-71	P92-04 (or 95-05[a])
	82-30B	31SW91-13	31SW91-38	36SE91-73	P92-05
	82-31B-E	31SW91-14	31SW91-39	36SE91-76	P92-06
	82-36A	31SW91-15	31SW91-41	36SE91-84	P92-07
	82-40A	31SW91-18	31SW91-42	92-01	P92-08
	82-42	31SW91-23	31SW91-46	92-03	P92-09
	82-51	31SW91-24	31SW91-50	92-05	31SW93-198-2
	82-52	31SW91-25	31SW91-52	92-07	31SW93-200-4
	88-85	31SW91-26	31SW91-53	92-08	36SE93-201-2
	31SW91-02	31SW91-27	31SW91-54	92-09	95-01[a]
					95-03[a]
Shallow Zone (NSS)	31SW93-194	31SW93-197-5			
	31SW93-195				
	31SW93-196				

Table 4.8-3. Proposed Ground-Water-Level Measurement Network for OU III (Continued)

Location	Well Number			
Lower Mancos (millsite and NSS)	31SW93-197-4 31SW93-200-3	31SW93-202-2 31SW93-203-2	31SW93-204-2	
Lower Dakota Sandstone (upgradient, millsite, downgradient, and NSS)	92-12 92-13	31SW93-197-3 31SW93-200-2 95-07[a]		
Lower Dakota Sandstone/Burro Canyon Aquifer (downgradient)	83-70			
Burro Canyon Aquifer (upgradient, millsite, downgradient, and NSS)	92-02 92-04 92-06	92-10 93-01	31SW93-197-2 31SW93-200-1 31NE93-205	95-02[a] 95-04[a] 95-06[a] 95-08[a]

[a]Proposed new well identification; wells to be installed October/November 1995.

Wells that have been omitted from the original Baseline Characterization list (Table 3.3-1, *Baseline Characterization Data Summary*, DOE 1994b) because they have since been abandoned or are typically dry, include 82–41, 82–45B, 82–46, 82–57, 84–74, 84–75, 84–76, 84–77, 31SW91–21, and 31SW91–22. Wells not included in the Baseline Characterization but added to the water-level measurement network include:

- Wells 31SW93–198–2, 31SW93–200–4, and 36SE93–201–2 included as new upper flow system wells on the MMTS.
- Wells 31SW93–194, 31SW93–195, 31SW93–196, and 31SW93–197–5 included as NSS shallow zone wells; water levels will allow assessment of ground-water flux from the NSS to the MMTS.
- Wells 31SW93–202–2, 31SW93–203–2, 31SW93–204–2 included as new first-water lower Mancos Shale wells on the millsite's north boundary; water levels will allow assessment of ground-water flux to the MMTS from the north.
- Wells 31SW93–200–2 and 31SW93–200–3 included as new lower Dakota Sandstone and lower Mancos Shale wells, respectively, will allow continued monitoring of vertical hydraulic gradients between hydrostratigraphic units near the western boundary of the MMTS.
- Wells 31SW93–197–3 and 31SW93–197–4 included as new lower Dakota Sandstone and lower Mancos Shale wells, respectively, will allow continued monitoring of vertical hydraulic gradients between hydrostratigraphic units near the southeast corner of the MMTS.

- Wells 93-01, 31SW93-197-2, 31SW93-200-1, and 31NE93-205 included as new Burro Canyon wells; water levels will allow local maps of potientiomeytric head contours to be constructed to monitor hydraulic gradients and flow directions.

- Wells 95-02, 95-04, 95-06, and 95-08 included as proposed new Burro Canyon downgradient of the millsite; water levels will allow local maps of potentiometric head contours to be constructed to monitor hydraulic gradients and flow directions.

- Wells 95-01, 95-03, and 95-05 included as proposed new upper flow system wells downgradient of the millsite; water levels (when compared with water levels from paired Burro Canyon wells 95-02, 95-04, and 95-06, respectively) will allow continued monitoring of vertical hydraulic gradients between hydrostratigraphic units.

- Well 95-07 included as proposed new lower Dakota Sandstone well cross-gradient of the millsite; water levels will allow local maps of potentiometric head contours to be constructed to monitor hydraulic gradients and flow directions; this well will also provide a water quality monitoring point in the Dakota Sandstone between the millsite and the City of Monticello.

Local seeps and springs will also be monitored for flow during the ground-water level measurements events. The seeps will be used to approximate the ground-water elevation at the respective locations and to assess the relative significance of flow at each area. The seeps and springs that will be monitored for flow are identified in Section 4.8.2 and are shown in map view in Plate 2-2. The location of each seep and spring will be surveyed for horizontal and vertical position, as described in Section 2.7 of the Field Sampling Plan.

The water-level measurement well network will be periodically reviewed and updated as necessary to accommodate project objectives throughout the OU III RI/FS project. This may include adding or subtracting wells from the network and/or changing the frequency of measurements.

Ground-Water-Level Monitoring Frequency

Ground-water levels in the monitoring wells will be measured on a monthly basis until it is judged that sufficient data has been obtained to characterize seasonal water level fluctuations. The frequency will subsequently be reduced to a quarterly basis for the remainder of the project. Ground-water-level monitoring field activities will be concurrent with surface water discharge measurement activities described in the following section.

4.8.4 Surface Water Quality Monitoring

Sampling Locations

Surface water samples will be collected at 18 sites for laboratory analysis under the Annual Monitoring Task. The surface water sampling sites are summarized in Table 4.8-4 according

to general location relative to the millsite. The locations of the surface water quality sampling sites are displayed in Plate 2-2.

Table 4.8-4. Proposed Surface Water Sampling Locations

Upgradient	Millsite	Downgradient
SW92-01 (South Creek) SW92-02 (North Creek) SW92-03 (Montezuma Creek) SW95-01 (Vega Creek above Montezuma Creek confluence)	W-2 SW92-04 SW92-05 Carbonate Seep North Drainage Slade Spring	W-4 SW92-06 Sorenson SW92-07 SW92-08 SW92-09 Montezuma Canyon SW94-01 Cabin Spring

As indicated in Table 4.8-4, surface water samples will be collected from four stream locations upgradient of or background to the millsite: SW92-01 (South Creek), SW92-02 (North Creek), SW92-03 (Montezuma Creek), and SW95-01 (Vega Creek above Montezuma Creek confluence). (Montezuma Creek forms at the confluence of North and South Creeks). Surface water sampling sites on the millsite are: Slade Spring, North Drainage, Carbonate Seep, and W-2, which are located on tributaries to Montezuma Creek; and, SW92-04 and SW92-05, located on Montezuma Creek. Surface water sampling sites located on Montezuma Creek downgradient of the millsite are: W-4, SW92-06 Sorenson, SW92-07, SW92-08, SW92-09, SW94-01, and Montezuma Canyon.

With the exception of Slade Spring, W-5, SW94-01, and SW95-01 (see Table 4.8-4), the proposed surface water sampling sites correspond to those utilized during the Baseline Characterization program. Site W-5 (millsite location) was removed from the original Baseline Characterization surface water monitoring network prior to the October 1993 sampling round as a result permanent underground piping of Hall's Ditch in the area. Slade Spring was recently discovered and will be added to the sampling network to assess potential influx of COPCs to Montezuma Creek. A new site, SW95-01, will be established to assess water quality on Vega Creek upstream of the confluence with Montezuma Creek.
Site SW94-01 was originally established in 1994 to measure discharge on Montezuma Creek below the Vega Creek confluence. This site will be sampled as part of the Annual Monitoring Task to assess the cumulative impact of Vega Creek water quality on Montezuma Creek water quality.

Sampling Frequency

Surface water samples will be collected on a semiannual basis under the Annual Monitoring Task except at sites SW94-01 and SW95-01 where samples will be collected approximately quarterly for 1 year and then semiannually coinciding with the other scheduled semiannual sampling rounds. Samples at these sites will be analyzed for the inorganic parameters listed in Table 4.8-2 but will not be analyzed for TCL organic compounds. Field parameters to be measured will include alkalinity, temperature, pH, and electrical conductivity. The semiannual rounds will coincide with periods of typically high seasonal water levels (April)

and low seasonal water levels (October) and will be conducted concurrently with the groundwater sampling program described in the preceding section.

During the OU III RI/FS Project, surface water sites in the sampling and analysis network will be periodically reviewed. Sampling sites will be added to or subtracted from the network to accommodate specific changes in project needs or issues.

4.8.5 Surface Water Discharge Monitoring

Discharge Monitoring Locations

Surface water discharge will be quantitatively measured at 14 sites along Montezuma Creek (Plate 2-2). Discharge measurement sites located upstream of the millsite are: SW92-01 (South Creek), SW92-02 (North Creek), and SW92-03 (Montezuma Creek). Discharge measurement sites located on the millsite are: SW94-02, SW92-04, and SW92-05. Sites W-4, SW92-06, Sorenson, SW92-07, SW92-08, SW92-09, SW94-01, and Montezuma Canyon are located downstream of the millsite. Discharge will also be measured at site SW95-01 on Vega Creek upstream from the Montezuma Creek confluence. The methods for determining stream discharge are detailed in Section 2.4.8 of the FSP.

Eleven additional sites that are either surface seeps or small tributaries to Montezuma Creek will be inspected for surface water discharge. Sites W-2, Carbonate Seep, Slade Spring, Goodknight Spring, and North Drainage are located on the millsite. Sites Pehrson Seep 1, Pehrson Seep 2, and Clay Hill Seep are located on the hillside north of the millsite. Site Upper North Drainage is located in the prominent drainage ravine north of the millsite. Site Cabin Spring is located at the abandoned cabin next to Montezuma Creek just upstream of the Vega Creek confluence. Site Adams Spring is located approximately 2700 ft east of the millsite at the base of the hillslope north of Clay Hill Drive. At these sites, flow will be qualitatively assessed and noted. If sufficient channel flow is observed, discharge will be quantified according to the method described in Section 2.4.8 of the FSP.

Discharge from additional seeps and springs identified during monitoring activities will be noted in the field logbook.

Discharge Monitoring Frequency

Surface water discharge measurements will be taken on a monthly basis until it has been judged that sufficient data has been obtained to characterize seasonal discharge fluctuations. The frequency will subsequently be reduced to a quarterly basis for the remainder of the project. Surface water-water discharge monitoring activities will be concurrent with groundwater-level measurement activities. Also, at all surface water sites that are sampled for water quality and quantitative discharge measurements are possible, discharge will be measured immediately before or after sampling.

4.8.6 Analytical Program

All ground-water and surface water samples collected during under the Annual Monitoring Task will be submitted to the GJPO Analytical Chemistry Laboratory for analysis of the analytes listed in Table 4.8-2, which also identifies the respective laboratory analytical methods and reporting limits for the analytes. The analytes and analytical methods presented in Table 4.8-2 are a compilation of those identified previously in the sampling and analytical programs for the ERA, HHRA, and Ground-Water Modeling Tasks for surface water and ground-water media. The Rust methods referenced in Table 4.8-2 are described in *The Analytical Chemistry Handbook of Analytical and Sample-Preparation Procedures* (DOE [undated]b) and *Geotech Analytical Chemistry Laboratory Administrative Plan and Quality Control Procedures* (DOE [undated]a). Information regarding specific sample collection procedures, sample containers, preservation, holding times, and other field-related details for surface water and ground-water sampling are addressed in the project FSP.

4.9 Task 8: Potential Additional Studies

Additional studies may be warranted to provide further support for ground-water modeling output and/or for analysis of potential response action alternatives. The need for additional studies will be determined following completion of the ground-water modeling and risk assessment efforts. Examples of the types of studies that may be performed are:

- **Assess the impact of ground-water chemistry on contaminant mobility.** It is known that the ground-water concentrations of many contaminants are sensitive to major ion (for example bicarbonate) concentration, pH, and redox state. If ground-water chemistry changes, contaminants that were bound to the aquifer solids could be released. Ground-water chemistry changes could occur as a result of future land use changes at and in the vicinity of OU III. For example, changes in ground-water chemistry would be anticipated if, as currently proposed, a golf course is constructed at the present location of the millsite. Laboratory and/or field treatability tests could be used to evaluate the factors that will mostly likely affect contaminant mobility.

- **Investigate areas of contaminated ground-water discharge using dissolved radon or other COPCs.** The analysis of dissolved radon-222 (half-life of 3.8 days) in Montezuma Creek waters could be a useful tool in delineating areas of sediment contamination within the upper flow system aquifer or stream sediments. Local increases in radon-222 concentrations along the reach of Montezuma Creek may indicated both discharge areas of ground water to the stream and/or, depending on the concentration, areas where saturated contaminated sediments exist.

The need to perform any additional studies will be determined by DOE in conjunction with EPA and the State. Details of the studies will be elicited prior to the start of a study and will be documented in a program directive.

4.10 Task 9: Remedial Investigation Report

All aspects of the RI will be clearly documented in the RI report. The format of the RI report will be consistent with EPA guidelines specified in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988). A proposed outline for the RI report is presented in Table 4.10-1.

Table 4.10-1. Proposed Remedial Investigation Report Outline

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Section 4.0

Remedial Investigation

Tables

September 1995

Table 4.5-1. Wildlife that are Likely to Inhabit Southeastern Utah

MAMMALS			
dusky shrew	*Sorex obscurus*	bobcat	*Lynx rufus*
vagrent shrew	*Sorex vagrans*	yellow-bellied marmot	*Marmota flaviventris*
dwarf shrew	*Sorex nanus*	Gunnison's prairie dog	*Cynomys gunnisoni*
merriam shrew	*Sorex merriami*	white-tailed prairie dog	*Cynomys leucurus*
little brown myotis	*Myotis lucifugus*	white-tailed antelope squirrel	*Ammospermophilus leucurus*
cave myotis	*Myotis velifer*		
fringed myotis	*Myotis thysanodes*	rock squirrel	*Spermophilus variegatus*
long-eared myotis	*Myotis evotis*	spotted ground squirrel	*Citellus spilosoma*
California myotis	*Myotis californicus*	red squirrel	*Tamiascurus hudsonicus*
Yuma myotis	*Myotis yumanensis*	least chipmunk	*Tamias minimus*
long-legged myotis	*Myotis volans*	Botta's pocket gopher	*Thomomys bottae*
small-footed myotis	*Myotis subulatus*	northern pocket gopher	*Thomomys talpoides*
silver-haired bat	*Lasionycteris noctavigans*	Ord's kangaroo rat	*Dipodomys ordii*
western pipistrel	*Pipestrellus hesperus*	western harvest mouse	*Reithrodontomys megalotis*
big brown bat	*Eptesicus fuscus*	canyon mouse	*Peromyscus crinitus*
hoary bat	*Lasiurus cinereus*	pinon mouse	*Peromyscus truei*
spotted bat	*Euderma maculata*	deer mouse	*Peromyscus maniculatus*
western big-eared bat	*Plecotus townsendi*	rock mouse	*Peromyscus difficilis*
Mexican big-eared bat	*Plecotus phyllotis*	brush mouse	*Peromyscus boylei*
pallid bat	*Antrozous pallidus*	whitethroat woodrat	*Neotoma albigula*
big free-tail bat	*Tadarida molossa*	Mexican woodrat	*Neotoma mexicana*
raccoon	*Procyon lotor*	bushy-tailed woodrat	*Neotoma cinerea*
ringtail	*Bassariscus astutus*	sagebrush vole	*Lagurus curtatus*
badger	*Taxidae taxus*	long-tailed vole	*Microtus longicaudus*
striped skunk	*Mephitis mephitis*	muskrat	*Ondatra zibethica*
spotted skunk	*Spilogale putorius*	porcupine	*Erethizon dorsatum*
river otter	*Lutra canadensis*	beaver	*Castor canadensis*
longtail weasel	*Mustela frenata*	black-tailed jackrabbit	*Lepus californicus*
black-footed ferret	*Mustela nigripes*	mountain cottontail	*Silvilagus nuttali*
coyote	*Canis latrans*	desert cottontail	*Silvilagus auduboni*
red fox	*Vulpes fulva*	mule deer	*Odocoileus hemionus*
gray fox	*Urocyon cinereoargenteus*	pronghorn	*Antilocapra amiricana*
mountain lion	*Felis concolor*	bighorn sheep	*Ovis canadensis*
BIRDS			
Clark's grebe	*Aechmophorus clarkii*	black-crowned night-heron	*Nycticorax nycticorax*
western grebe	*Aechmophorus occidentalis*		
eared grebe	*Podiceps nigricollis*	green-backed heron	*Butorides striatus*
pied-billed grebe	*Podilymbus podiceps*	snowy egret	*Egretta thula*
American bittern	*Botaurus lentiginosus*	great blue heron	*Ardea herodias*

Table 4.5-1. Wildlife that are Likely to Inhabit Southeastern Utah (continued)

BIRDS (continued)

gray jay	*Perisoreus canadensis*
Clark's nutcracker	*Nucifraga columbiana*
black-billed magpie	*Pica pica*
American crow	*Corvus caurinus*
common raven	*Corvus corax*
plain titmouse	*Parus inornatus*
black-capped chickadee	*Parus atricapillus*
mountain chickadee	*Parus gambeli*
bushtit	*Psaltriparus minimus*
brown creeper	*Certhia americanus*
white-breasted nuthatch	*Sitta carolinensis*
red-breasted nuthatch	*Sitta canadensis*
pygmy nuthatch	*Sitta pygmaea*
house wren	*Triglodytes aedon*
Bewick's wren	*Thryomanes bewickii*
canyon wren	*Catherpes mexicanus*
rock wren	*Salpinctes obsoletus*
golden-crowned kinglet	*Regulus satrapa*
ruby-crowned kinglet	*Regulus calendula*
blue-gray gnatcatcher	*Polioptila caerulea*
western bluebird	*Sialia mexicana*
mountain bluebird	*Sialia currucoides*
Townsend's solitaire	*Myadestes townsendi*
Swainson's thrush	*Catharus ustulatus*
hermit thrush	*Catharus guttatus*
American robin	*Turdus migratorius*
logerhead shrike	*Lanius ludovicianus*
northern shrike	*Lanius excubitor*
northern mockingbird	*Mimus polyglottos*
sage thrasher	*Oreoscoptes montanus*
bohemian waxwing	*Bombycilla garrulus*
cedar waxwing	*Bombycilla cedrorum*
European starling	*Sturnus vulgaris*
gray vireo	*Vireo vicinior*
solitary vireo	*Vireo solitarius*
orange-crowned warbler	*Vermivora celata*
Virginia's warbler	*Vermivora virginiae*
yellow-rumped warbler	*Dendroica coronata*
common barn owl	*Tyto alba*
short-eared owl	*Asio flammeus*
long-eared owl	*Asio otus*
black-throated gray warbler	*Dendroica nigrescens*
Grace's warbler	*Dendroica graciae*
yellow warbler	*Dendroica petechia*
common yellowthroat	*Geothlypis trichas*
yellow-breasted chat	*Icteria virens*
black-headed grosbeak	*Pheucticus melanocephalus*
blue grosbeak	*Guiraca caerulea*
indigo bunting	*Passerina cyanea*
Lazuli bunting	*Passerina amoena*
green-tailed towhee	*Pipilo chlorurus*
rufous-sided towhee	*Pipilo erythrophthalmus*
vesper sparrow	*Pooecetes gramineus*
savannah sparrow	*Passerculus sandwichensis*
song sparrow	*Melospiza melodia*
lark sparrow	*Chondestes grammacus*
black-throated sparrow	*Amphispiza bilineata*
sage sparrow	*Amphispiza belli*
American tree sparrow	*Spizella arborea*
chirping sparrow	*Spizella passerina*
Brewer's sparrow	*Spizella breweri*
dark-eyed junco	*Junco hyemalis*
white-crowned sparrow	*Zonotrichia leucophrys*
Lincoln's sparrow	*Melospiza lincolnii*
western meadowlark	*Sturnella neglecta*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
red-winged blackbird	*Agelaius phoeniceus*
Brewer's blackbird	*Euphagus cyanocephalus*
brown-headed cowbird	*Molothrus ater*
Scott's oriole	*Icterus parisorum*
northern oriole	*Icterus galbula*
western tanager	*Piranga ludoviciana*
house sparrow	*Passes domesticus*
pine siskin	*Carduelis pinus*
American goldfinch	*Carduelis tristis*
lesser goldfinch	*Carduelis psaltria*
red crossbill	*Loxia curvirostra*
pine grosbeak	*Pinicola enucleator*
rosy finch	*Leucosticte arctoa*
Cassin's finch	*Carpodacus cassinii*
house finch	*Carpodacus mexicanus*
evening grosbeak	*Coccothraustes vespertinus*

Table 4.5-1. Wildlife that are Likely to Inhabit Southeastern Utah (continued)

BIRDS (continued)

white-faced ibis	*Plegadis chihi*
Canada goose	*Branta canadensis*
mallard	*Anas platyrhynchos*
gadwall	*Anas strepera*
green-winged teal	*Anas crecca*
American wigeon	*Anas americana*
northern pintail	*Anas acuta*
northern shoveler	*Anas clypeata*
blue-winged teal	*Anas discors*
cinnamon teal	*Anas cyanoptera*
ruddy duck	*Oxyura jamaicensis*
redhead	*Aythya americana*
common goldeneye	*Bucephala clangula*
bufflehead	*Bucephala albeola*
common merganser	*Mergus merganser*
virginia rail	*Rallus limicola*
sora	*Porzana carolina*
American coot	*Fulica americana*
killdeer	*Charadrius vociferus*
long-billed curlew	*Numenius americanus*
spotted sandpiper	*Actitis macularia*
Wilson's phalarope	*Phalaropus tricolor*
common snipe	*Gallinago gallinago*
herring gull	*Larus argentatus*
turkey vulture	*Cathartes aura*
golden eagle	*Aquila chrysaetos*
bald eagle	*Haliaeetus leucocephalus*
northern harrier	*Circus cyaneus*
sharp-shinned hawk	*Accipiter striatus*
Cooper's hawk	*Accipiter cooperii*
northern goshawk	*Accipiter gentilis*
redtailed hawk	*Buteo jamaicensis*
Swainson's hawk	*Buteo swainsoni*
rough-legged hawk	*Buteo lagopus*
ferruginous hawk	*Buteo regalis*
osprey	*Pandion haliaetus*
American kestrel	*Falco sparverius*
prairie falcon	*Falco mexicanus*
sage grouse	*Centrocercus urophasianus*
chukar	*Alectoris chukar*
wild turkey	*Meleagris gallopavo*
band-tailed pigeon	*Columba fasciata*
rock dove	*Columba livia*
mourning dove	*Zenaida macroura*
yellow-billed cuckoo	*Coccyzus erythropthalmus*
great horned owl	*Bubo virginianus*
western screech owl	*Otus kennicottii*
flamulated owl	*Otus flammeolus*
northern saw-whet owl	*Aegolius acadicus*
burrowing owl	*Athene cunicularia*
common poorwill	*Phalaenoptilus nuttallii*
common nighthawk	*Chordeiles minor*
white-throated swift	*Aeronautes saxatalis*
black-chinned hummingbird	*Archilochus alexandri*
broad-tailed hummingbird	*Selasphorus platycercus*
belted kingfisher	*Ceryle alcyon*
northern flicker	*Colaptes auratus*
Lewis' woodpecker	*Melanerpes lewis*
Williamson's sapsucker	*Sphyrapicus thyroideus*
red-naped sapsucker	*Sphyrapicus nuchalis*
downy woodpecker	*Picoides pubescens*
hairy woodpecker	*Picoides villosus*
three-toed woodpecker	*Picoides tridactylus*
western kingbird	*Tyrannus verticalis*
Cassin's kingbird	*Tyrannus vociferans*
ash-throated flycatcher	*Myiarchus tuberculifer*
olive-sided flycatcher	*Contopus borealis*
western wood-pewee	*Contopus sordidulus*
Say's phoebe	*Sayornis saya*
gray flycatcher	*Empidonax wrightii*
dusky flycatcher	*Empidonax oberholseri*
Hammond's flycatcher	*Empidonax hammondii*
willow flycatcher	*Empidonax traillii*
western flycatcher	*Empidonax difficilis*
horned lark	*Eremophila alpestris*
tree swallow	*Tachycineta bicolor*
violet-green swallow	*Tachycineta thalassina*
bank swallow	*Riparia riparia*
northern rough-winged swallow	*Stelgidopteryx serripennis*
cliff swallow	*Hirundo pyrrhonota*
barn swallow	*Hirundo rustica*
scrub jay	*Aphelocoma coerulescens*
pinon jay	*Gymnorhinus cyanocephalus*
Steller's jay	*Cyanocitta stelleri*

Table 4.5-1. Wildlife that are Likely to Inhabit Southeastern Utah (continued)

REPTILES	
Utah night lizard	*Xantusia vigilis utahensis*
collared lizard	*Crotaphytus collaris*
leopard lizard	*Crotaphytus wislizenii*
orange-headed spiny lizard	*Sceloporus magister cephaloflavus*
northern plateau lizard	*Sceloporus undulatus elongatus*
sagebrush lizard	*Sceloporus graciosus*
northern side-blotched lizard	*Uta stansburiana stansburiana*
tree lizard	*Ususaurus ornatus*
mountain short-horned lizard	*Phrynosoma douglassi hernandesi*
northern whiptail	*Cnemidophorus tigris septentrionalis*
plateau whiptail	*Cnemidophorus velox*
red racer	*Masticophis flagellum piceus*
western yellow-bellied racer	*Coluber constrictor mormon*
striped whipsnake	*Masticophis taeniatus*
Great Basin gophersnake	*Pituophis melanoleucus deserticola*
California kingsnake	*Lampropeltis getulus californiae*
black-necked garter snake	*Thamnophis cyrtopsis*
western garter snake	*Thamnophis elegans*
Mesa Verde night snake	*Hypsiglena torguata loreala*
midget-faded rattlesnake	*Crotalus viridis concolor*
AMPHIBIANS	
Great Basin spadefoot	*Scaphiopus intermontanus*
Woodhouse's toad	*Bufo woodhousei*
Great Plains toad	*Bufo cognatus*
red-spotted toad	*Bufo punctatus*
canyon treefrog	*Hyla arenicolor*
leopard frog	*Rana pipiens*
FISH	
Colorado squawfish	*Ptychocheilus lucius*
bonytail chub	*Gila elegans*
roundtail chub	*Gila robusta*
humpback chub	*Gila cypha*
flannelmouth sucker	*Catostomus latipinnis*
bluehead sucker	*Catostomus discobolus*
fathead minnow	*Pimephales promelas*
speckled dace	*Rhinichthys cataractae*
redside shiner	*Richardsonium balteatus*
red shiner	*Neotropis lutrensis*
sand shiner	*Neotropis stramineus*
plains killifish	*Fundulus zebrinus*
cutthroat trout	*Oncorhynchus clarki*

Table 4.5-4. Toxicity Benchmark Values for the Oral ingestion Exposure Route.

Analyte	Toxicity Benchmark Value (mg/kg bw/day)	Species	Endpoint	Reference
Aluminum	0.627 - >1.762 mg/l	Toad (Bufo americanus)	96 hr LC50	Devillers and Exbrayat, 1992
	0.403 - >1.018 mg/l	Frog (Rana pipiens)	96 hr LC50	Devillers and Exbrayat, 1992
Antimony	NA			
Arsenic	14	Mallard	NOAEL @ 100 ppm in diet for behavior (LOAEL was 300 ppm for behavior and growth). Converted with 0.14 kg diet/kg bw from Camardese et al., 1990.	Camardese et al., 1990 Whitworth et al., 1991
	3.8	Rat	NOAEL (LOAEL was 22.5 mg/kg bw/day for growth, liver lesions)	Schroeder et al., 1968
	2.0	Grazers	Maximum tolerated in diet 50 ppm, dry weight basis (convert with 0.04 kg diet/kg bw from Sax, 1984)	Bodek et al., 1988
Barium	1000	Chicken	NOAEL	Johnson et al., 1960
	5.1	Rat	LOAEL for cardiovascular effects. These effects unlikely to affect population success.	Perry et al., 1983
Beryllium	0.54	Rat	NOAEL for weight loss	Opresko et al., 1993

NA Data unavailable in the literature reviewed.
LD50 Dose lethal to 50% of the test population.
LC50 Concentration lethal to 50% of the test population.
LDLo Lowest lethal test concentration.
TDLo Lowest toxic test dose.
TCLo Lowest toxic test concentration.
NOAEL No Observed Adverse Effects Level.
LOAEL Lowest Observed Adverse Effects Level.
NTEL No Toxic Effects Level.

Table 4.5-4. Toxicity Benchmark Values for the Oral ingestion Exposure Route (continued)

Analyte	Toxicity Benchmark Value (mg/kg bw/day)	Species	Endpoint	Reference
Cadmium	2.0	Mallard	NOAEL for adults; kidney lesions in ducklings	Cain et al., 1983 White et al., 1978
	2.5	Rat	NOAEL for behavior, condition, body weight, food consumption (30 ppm)	Groten et al., 1991
	0.002	Grazers	Maximum tolerated 0.05 ppm dwb, converted with 0.04 kg diet/kg bw, (Sax, 1984))	Bodek et al., 1988
	9 - 30 ug/l (CdSO4)	Frog *(Xenopus laevis)*	NTEL (mortality, body weight, inhibition of larval development)	Devillers and Exbrayat, 1992
Chromium (III)	NA			
Cobalt	NA			
Copper	29	Mallard duck	NOAEL for weight gain, mortality	Opresko et al., 1993
	22.8	Chicken	NOAEL for weight gain, mortality	Opresko et al., 1993
	36	Rat	LOAEL for decreased hemoglobin and increased SGOT was 36 mg/kg bw/day for 49 day exposure.	Suttle and Mills, 1966
	0.4	Sheep	Toxic. Maximum chronic intake tolerated for grazers is 25-300 ppm in diet, dwb. Daily intake calculated with 0.04 kg diet/kg bw for cow (Sax, 1984).	Doherty et al., 1969 Bodek et al., 1988

NA Data unavailable in the literature reviewed.
LD50 Dose lethal to 50% of the test population.
LC50 Concentration lethal to 50% of the test population.
LDLo Lowest lethal test concentration.
TDLo Lowest toxic test dose.
TCLo Lowest toxic test concentration.
NOAEL No Observed Adverse Effects Level.
LOAEL Lowest Observed Adverse Effects Level.
NTEL No Toxic Effects Level.

Table 4.5-4. Toxicity Benchmark Values for the Oral ingestion Exposure Route (continued)

Analyte	Toxicity Benchmark Value (mg/kg bw/day)	Species	Endpoint	Reference
Iron	No bird values			
	100	Rat	Estimated from dose response curve with minimum LD 5.3 and maximum LD 500, most likely 256 mg/kg.	Venugopal and Luckey, 1978
Lead	14.5	Kestrel	NOAEL (for survival, histopathology, organ weight, and reproduction) from diet of 50 ppm converted with 0.29 kg diet/kg bw (kestrel)(EPA, 1993b).	Franson et al., 1983 Pattee, 1984
	3.0	Mice and rats	LOAEL of 25 mg/kg diet lead salts. Caused impaired reproduction. Converted with 0.12 kg diet/kg bw (Sax, 1984).	Venugopal and Luckey, 1978
	1.2	Grazer	Maximum tolerated in diet 30 ppm, dwb. Convert with 0.04 kg diet/kg bw (Sax, 1984).	Bodek et al., 1988
	0.47 - 0.9 mg/l (PbNO3)	Toad *(Bufo arenarum)*	48 hr LC50	Devillers and Exbrayat, 1992

NA Data unavailable in the literature reviewed.
LD50 Dose lethal to 50% of the test population.
LC50 Concentration lethal to 50% of the test population.
LDLo Lowest lethal test concentration.
TDLo Lowest toxic test dose.
TCLo Lowest toxic test concentration.
NOAEL No Observed Adverse Effects Level.
LOAEL Lowest Observed Adverse Effects Level.
NTEL No Toxic Effects Level.

Table 4.5-4. Toxicity Benchmark Values for the Oral ingestion Exposure Route (continued)

Analyte	Toxicity Benchmark Value (mg/kg bw/day)	Species	Endpoint	Reference
Manganese	No bird values	-	-	
	290	Rat	NOAEL for mortality for chronic exposure; 930 the LOAEL for mortality. Levels from 140 to 600 mg/kg/day cause biochemical and behavior changes. The recommended value may cause these effects but probably will not affect population success.	National Toxicity Program, 1993
	80	Grazer	Maximum chronic tolerated dietary level is 400 - 2000 ppm dwb (converted with 0.04 kg diet/kg bw (Sax, 1984))	Bodek et al., 1988
Mercury	0.18	Chicken, starling	Reproductive effects, kidney lesions	Thaxton et al., 1975; Nicholson and Osborn, 1984
	1.8	Mouse	Renal tumors	Mitsumori et al., 1981
	0.75	Mink	NOAEL	Aulerich et al., 1974
Nickel	24.15	Rat	NOAEL for reproduction	Opresko et al., 1993
Selenium	0.88	Chicken	Reproductive effects	Ort and Latshaw, 1978
	0.57	Mouse	LOAEL for reproductive effects	Opresko et al., 1993
	0.08	Grazer	Maximum tolerated in diet is 2 ppm dwb (convert with 0.04 kg diet/kg bw (Sax, 1984)). Alkali disease occurs at 0.12 mg/kg bw/day.	Bodek et al., 1988

NA Data unavailable in the literature reviewed.
LD50 Dose lethal to 50% of the test population.
LC50 Concentration lethal to 50% of the test population.
LDLo Lowest lethal test concentration.
TDLo Lowest toxic test dose.
TCLo Lowest toxic test concentration.
NOAEL No Observed Adverse Effects Level.
LOAEL Lowest Observed Adverse Effects Level.
NTEL No Toxic Effects Level.

Table 4.5-4. Toxicity Benchmark Values for the Oral ingestion Exposure Route (continued)

Analyte	Toxicity Benchmark Value (mg/kg bw/day)	Species	Endpoint	Reference
Silver	65	Rat	NOAEL	Walker, 1971
	52	Pig	NOAEL	Van Vleet, 1976
Thallium	23.7	Ring-necked pheasant	LD50	Hudson et al., 1984
Uranium	100 ug/l (67 pCi/L alpha)	Human	NOAEL for kidney toxicity based on drinking water ingestion	Wrenn et al., 1985
	86	Black duck	NOAEL for 6 week study	Opresko et al., 1993
	4.42 mg/kg diet	Game bird	Background in game bird ration	Robinson et al., 1984
	2.8	Rabbit	30 day LOAEL for histopathological changes in kidney; unlikely to have population effects	Opresko et al., 1993
	1.36 mg/kg diet	Rabbit	Background in rabbit chow	Robinson et al., 1984
Vanadium	NA			
Zinc	1.7	Mallard duck	LOAEL for blood chemistry; mortality	Opresko et al., 1993
	75	Rat, pig	NOAEL	Sutton and Nelson, 1937 Lewis et al., 1957
	40	Grazer	Maximum tolerated in diet 300-1000 ppm, dwb.	Bodek et al., 1988
	3.6 mg/l	Frog *(Xenopus laevis)*	EC50 (malformations)	Devillers and Exbrayat, 1992

NA Data unavailable in the literature reviewed.
LD50 Dose lethal to 50% of the test population.
LC50 Concentration lethal to 50% of the test population.
LDLo Lowest lethal test concentration.
TDLo Lowest toxic test dose.
TCLo Lowest toxic test concentration.
NOAEL No Observed Adverse Effects Level.
LOAEL Lowest Observed Adverse Effects Level.
NTEL No Toxic Effects Level.

Table 4.5-5. Toxicity Benchmark Values for Plants and Soil Fauna

Analyte	Toxicity Benchmark Value (mg/kg soil)	Species	Endpoint	Reference
Aluminum	10	plants	recommended benchmark value	Suter et al., 1993
	2500 - 2800	woodlouse	55-75% survival over 6-12 weeks	ICF Kaiser, 1989
Antimony	5	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			
Arsenic	> 2	barley, alfalfa	obvious damage to plants occurs at soil concentrations above this	ICF Kaiser, 1989
	10	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			
Barium	500	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			
Beryllium	10	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			
Cadmium	5	plants	phytotoxic level in soils	ICF Kaiser, 1989
	2	plants	recommended benchmark value	Suter et al., 1993
	20	earthworms	threshold for adverse effects on growth and sexual maturation	ICF Kaiser, 1989
Chromium	$\geq$ 5	tobacco, other agricultural crops	phytoxic level in soils	ICF Kaiser, 1989
	2	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			
Cobalt	25	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			

NA Data unavailable in the literature reviewed.
NOEC No Observed Effects Concentration

Table 4.5-5. Toxicity Benchmark Values for Plants and Soil Fauna (continued)

Analyte	Toxicity Benchmark Value (mg/kg soil)	Species	Endpoint	Reference
Copper	100	plants	phytotoxic level in soils	ICF Kaiser, 1989
	40	plants	recommended benchmark value	Suter et al., 1993
	60	earthworm	threshold for adverse effects on growth and sexual maturation	ICF Kaiser, 1989
Iron	1000	woodlice species	significant increase in respiratory rate	ICF Kaiser, 1989
	Values for plants unavailable in the literature reviewed			
Lead	100	plants	phytotoxic level in soils	ICF Kaiser, 1989
	50	plants	recommended benchmark value	Suter et al., 1993
	95	invertebrates	NOEC	ICF Kaiser, 1989
Manganese	500	plants	recommended benchmark value	Suter et al., 1993
	Values for soil fauna unavailable in the literature reviewed			
Mercury	10	plants	concentration in sludge identified as potentially toxic to plants and animals	ICF Kaiser, 1989
	0.3	plants	recommended benchmark value	Suter et al., 1993
Nickel	20	potatoes	soil concentration causing damage	ICF Kaiser, 1989
	25	plants	recommended benchmark value	Suter et al., 1993
	500 (Value of 50 after UF of 10 applied)	earthworms	reduced growth and reproduction	ICF Kaiser, 1989
Selenium	1	wheat and buckwheat	decreased growth rate	ICF Kaiser, 1989
Silver	2	plants	recommended benchmark value	Suter et al., 1993

NA Data unavailable in the literature reviewed.
NOEC No Observed Effects Concentration

Table 4.5-5. Toxicity Benchmark Values for Plants and Soil Fauna (continued)

Analyte	Toxicity Benchmark Value (mg/kg soil)	Species	Endpoint	Reference
Thallium	NA			
Vanadium	2.5 Values for soil fauna unavailable in the literature reviewed	plants	recommended benchmark value	Suter et al., 1993
Zinc	93	chrysanthemums	decreased growth	ICF Kaiser, 1989
	20	plants	recommended benchmark value	Suter et al., 1993
	100	woodlouse	NOEC; adverse effects (LC50) in earthworms at 662 mg/kg	ICF Kaiser, 1989

NA Data unavailable in the literature reviewed.
NOEC No Observed Effects Concentration

Table 4.5-12. Preliminary Daily Intakes (ug/kg bw/day) Based on Surface Water Ingestion for Terrestrial Wildlife and Birds

	Passerine [Daily Intake (µg/kg bw/day)]						Raptor [Daily Intake (µg/kg bw/day)]						Small Herbivore [Daily Intake (µg/kg bw/day)]					
	Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient	
Analyte	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al	108.3	362.5	110.8	340.0	251.8	887.5	108.3	362.5	110.8	340.0	251.8	887.5	86.6	290.0	88.6	272.0	201.4	710.0
As	1.1	2.8	34.9	312.5	0.7	3.8	1.1	2.8	34.9	312.5	0.7	3.8	0.9	2.2	27.9	250.0	0.6	3.0
Ba	21.0	35.3	14.0	29.3	16.1	25.8	21.0	35.3	14.0	29.3	16.1	25.8	16.8	28.2	11.2	23.4	12.9	20.6
Be	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	1.7	1.7	ND	ND	ND	ND	1.7	1.7	ND	ND	ND	ND	1.3	1.3	ND	ND	ND	ND
Cr	1.2	1.2	0.0	0.0	1.3	6.6	1.2	1.2	0.0	0.0	1.3	6.6	1.0	1.0	0.0	0.0	1.0	5.3
Cu	2.5	2.5	1.6	16.3	0.6	2.7	2.5	2.5	1.6	16.3	0.6	2.7	2.0	2.0	1.3	13.0	0.5	2.1
Fe	179.0	417.5	120.2	350.0	251.2	1112.5	179.0	417.5	120.2	350.0	251.2	1112.5	143.2	334.0	96.1	280.0	201.0	890.0
Hg	ND	ND	0.1	0.1	ND	ND	ND	ND	0.1	0.1	ND	ND	ND	ND	0.0	0.0	ND	ND
Mn	66.5	250.0	41.9	196.3	46.0	115.0	66.5	250.0	41.9	196.3	46.0	115.0	53.2	200.0	33.5	157.0	36.8	92.0
Mo	2.5	5.1	43.8	612.5	3.5	22.7	2.5	5.1	43.8	612.5	3.5	22.7	2.0	4.0	35.0	490.0	2.8	18.2
Na	20299.7	50750.0	37890.0	26500.0	19943.1	42500.0	20299.7	50750.0	37890.0	26500.0	19943.1	42500.0	16239.8	40600.0	30312.0	21200.0	15954.5	34000.0
Ni	1.3	3.3	1.3	2.9	1.6	2.9	1.3	3.3	1.3	2.9	1.6	2.9	1.0	2.7	1.0	2.3	1.3	2.3
NO3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb	0.5	6.1	0.3	1.3	0.5	1.6	0.5	6.1	0.3	1.3	0.5	1.6	0.4	4.9	0.2	1.0	0.4	1.3
SO	55903.0	25000.0	150123.3	34500.0	96276.4	196750.0	55903.0	25000.0	150123.3	34500.0	96276.4	196750.0	44722.4	20000.0	120098.6	27600.0	77021.1	157400.0
Sb	0.2	0.5	0.2	0.6	0.2	0.5	0.2	0.5	0.2	0.6	0.2	0.5	0.2	0.4	0.2	0.4	0.1	0.4
Se	0.6	2.4	9.5	135.0	0.6	4.9	0.6	2.4	9.5	135.0	0.6	4.9	0.4	1.9	7.6	108.0	0.5	3.9
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
U	5.0	25.8	163.0	807.5	23.4	127.0	5.0	25.8	163.0	807.5	23.4	127.0	4.0	20.6	130.4	646.0	18.7	101.6
V	2.3	7.5	964.1	13000.0	5.2	70.0	2.3	7.5	964.1	13000.0	5.2	70.0	1.9	6.0	771.3	10400.0	4.2	56.0
Zn	2.9	8.5	3.1	9.6	6.2	21.7	2.9	8.5	3.1	9.6	6.2	21.7	2.3	6.8	2.5	7.7	4.9	17.3
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.5-12. Daily Intakes (ug/kg bw/day) Based on Surface Water Ingestion for Terrestrial Wildlife and Birds (continued)

	Large Herbivore [Daily Intake (µg/kg bw/day)]						Small Omnivore [Daily Intake (µg/kg bw/day)]						Large Omnivore [Daily Intake (µg/kg bw/day)]					
	Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient	
Analyte	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al	21.7	72.5	22.2	68.0	50.4	177.5	54.1	181.3	55.4	170.0	125.9	443.8	21.7	72.5	22.2	68.0	50.4	177.5
As	0.2	0.6	7.0	62.5	0.1	0.8	0.6	1.4	17.5	156.3	0.4	1.9	0.2	0.6	7.0	62.5	0.1	0.8
Ba	4.2	7.1	2.8	5.9	3.2	5.2	10.5	17.6	7.0	14.6	8.1	12.9	4.2	7.1	2.8	5.9	3.2	5.2
Be	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	0.3	0.3	ND	ND	ND	ND	0.8	0.8	ND	ND	ND	ND	0.3	0.3	ND	ND	ND	ND
Cr	0.2	0.2	0.0	0.0	0.3	1.3	0.6	0.6	0.0	0.0	0.6	3.3	0.2	0.2	0.0	0.0	0.3	1.3
Cu	0.5	0.5	0.3	3.3	0.1	0.5	1.3	1.3	0.8	8.1	0.3	1.3	0.5	0.5	0.3	3.3	0.1	0.5
Fe	35.8	83.5	24.0	70.0	50.2	222.5	89.5	208.8	60.1	175.0	125.6	556.3	35.8	83.5	24.0	70.0	50.2	222.5
Hg	ND	ND	0.0	0.0	ND	ND	ND	ND	0.0	0.0	ND	ND	ND	ND	0.0	0.0	ND	ND
Mn	13.3	50.0	8.4	39.3	9.2	23.0	33.3	125.0	21.0	98.1	23.0	57.5	13.3	50.0	8.4	39.3	9.2	23.0
Mo	0.5	1.0	8.8	122.5	0.7	4.5	1.3	2.5	21.9	306.3	1.7	11.4	0.5	1.0	8.8	122.5	0.7	4.5
Na	4059.9	10150.0	7578.0	5300.0	3988.6	8500.0	10149.9	25375.0	18945.0	13250.0	9971.6	21250.0	4059.9	10150.0	7578.0	5300.0	3988.6	8500.0
Ni	0.3	0.7	0.3	0.6	0.3	0.6	0.6	1.7	0.7	1.4	0.8	1.5	0.3	0.7	0.3	0.6	0.3	0.6
NO3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb	0.1	1.2	0.1	0.3	0.1	0.3	0.2	3.1	0.2	0.6	0.3	0.8	0.1	1.2	0.1	0.3	0.1	0.3
SO	11180.6	5000.0	30024.7	6900.0	19255.3	39350.0	27951.5	12500.0	75061.6	17250.0	48138.2	98375.0	11180.6	5000.0	30024.7	6900.0	19255.3	39350.0
Sb	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.3	0.1	0.3	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.1
Se	0.1	0.5	1.9	27.0	0.1	1.0	0.3	1.2	4.8	67.5	0.3	2.5	0.1	0.5	1.9	27.0	0.1	1.0
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
U	1.0	5.2	32.6	161.5	4.7	25.4	2.5	12.9	81.5	403.8	11.7	63.5	1.0	5.2	32.6	161.5	4.7	25.4
V	0.5	1.5	192.8	2600.0	1.0	14.0	1.2	3.7	482.0	6500.0	2.6	35.0	0.5	1.5	192.8	2600.0	1.0	14.0
Zn	0.6	1.7	0.6	1.9	1.2	4.3	1.5	4.3	1.5	4.8	3.1	10.8	0.6	1.7	0.6	1.9	1.2	4.3
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.5-14. Preliminary Hazard Quotients Based on To Be Considered Values for Terrestrial Wildlife and Birds for the Surface Water Ingestion Pathway

	Passerine [Daily Intake (µg/kg bw/day)]						Raptor [Daily Intake (µg/kg bw/day)]						Small Herbivore [Daily Intake (µg/kg bw/day)]					
	Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient	
Analyte	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
As	7.86E-05	1.96E-04	2.49E-03	2.23E-02	5.00E-05	2.70E-04	7.86E-05	1.96E-04	2.49E-03	2.23E-02	5.00E-05	2.70E-04	2.32E-04	5.79E-04	7.35E-03	6.58E-02	1.47E-04	7.95E-04
Ba	2.10E-05	3.53E-05	1.40E-05	2.93E-05	1.61E-05	2.58E-05	2.10E-05	3.53E-05	1.40E-05	2.93E-05	1.61E-05	2.58E-05	3.29E-03	5.53E-03	2.20E-03	4.59E-03	2.53E-03	4.04E-03
Be	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cu	8.71E-05	8.71E-05	5.52E-05	5.61E-04	2.16E-05	9.22E-05	8.71E-05	8.71E-05	5.52E-05	5.61E-04	2.16E-05	9.22E-05	1.35E-04	1.35E-04	8.53E-05	8.68E-04	3.33E-05	1.43E-04
Fe	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.43E-03	3.34E-03	9.61E-04	2.80E-03	2.01E-03	8.90E-03
Hg	ND	ND	2.78E-03	2.78E-03	ND	ND	ND	ND	2.78E-03	2.78E-03	ND	ND	ND	ND	2.22E-04	2.22E-04	ND	ND
Mn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.80E-04	1.43E-03	2.39E-04	1.12E-03	2.63E-04	6.57E-04
Mo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Na	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ni	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.14E-05	1.10E-04	4.31E-05	9.44E-05	5.30E-05	9.61E-05
NO3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb	3.28E-05	4.22E-04	2.07E-05	8.79E-05	3.62E-05	1.12E-04	3.28E-05	4.22E-04	2.07E-05	8.79E-05	3.62E-05	1.12E-04	1.27E-03	1.63E-02	3.00E-04	3.40E-03	1.40E-03	4.33E-03
SO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Se	6.25E-03	2.76E-02	1.08E-01	1.53E+00	6.53E-03	5.57E-02	6.25E-03	2.76E-02	1.08E-01	1.53E+00	6.53E-03	5.57E-02	7.72E-03	3.40E-02	1.33E-01	1.89E+00	8.07E-03	6.88E-02
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
U	5.76E-05	2.99E-04	1.90E-03	9.39E-03	2.72E-04	1.48E-03	5.76E-05	2.99E-04	1.90E-03	9.39E-03	2.72E-04	1.48E-03	1.41E-03	7.36E-03	4.66E-02	2.31E-01	6.69E-03	3.63E-02
V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn	1.72E-03	5.00E-03	1.81E-03	5.63E-03	3.62E-03	1.28E-02	1.72E-03	5.00E-03	1.81E-03	5.63E-03	3.62E-03	1.28E-02	3.12E-05	9.07E-05	3.28E-05	1.02E-04	6.56E-05	2.31E-04
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.5-14. Preliminary Hazard Quotients Based on To Be Considered Values for Terrestrial Wildlife and Birds for the Surface Water Ingestion Pathway (continued)

	Large Herbivore [Daily Intake (µg/kg bw/day)]						Small Omnivore [Daily Intake (µg/kg bw/day)]						Large Omnivore [Daily Intake (µg/kg bw/day)]					
	Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient		Up Gradient		On Site		Down Gradient	
Analyte	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
As	1.10E-04	2.75E-04	3.49E-03	3.13E-02	7.00E-05	3.78E-04	1.45E-04	3.62E-04	4.59E-03	4.11E-02	9.21E-05	4.97E-04	5.79E-05	1.45E-04	1.84E-03	1.64E-02	3.68E-05	1.99E-04
Ba	8.23E-04	1.38E-03	5.50E-04	1.15E-03	6.31E-04	1.01E-03	2.06E-03	3.46E-03	1.38E-03	2.87E-03	1.58E-03	2.52E-03	8.23E-04	1.38E-03	5.50E-04	1.15E-03	6.31E-04	1.01E-03
Be	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cu	1.26E-03	1.26E-03	8.00E-04	8.14E-03	3.13E-04	1.34E-03	8.42E-05	8.42E-05	5.33E-05	5.43E-04	2.08E-05	8.92E-05	3.37E-05	3.37E-05	2.13E-05	2.17E-04	8.33E-06	3.57E-05
Fe	3.58E-04	8.35E-04	2.40E-04	7.00E-04	5.02E-04	2.23E-03	8.95E-04	2.09E-03	6.01E-04	1.75E-03	1.26E-03	5.56E-03	3.58E-04	8.35E-04	2.40E-04	7.00E-04	5.02E-04	2.23E-03
Hg	ND	ND	5.56E-05	5.56E-05	ND	ND	ND	ND	1.39E-04	1.39E-04	ND	ND	ND	ND	1.33E-05	1.33E-05	ND	ND
Mn	1.66E-04	6.25E-04	1.05E-04	4.91E-04	1.15E-04	2.88E-04	2.38E-04	8.93E-04	1.50E-04	7.01E-04	1.64E-04	4.11E-04	9.50E-05	3.57E-04	5.99E-05	2.80E-04	6.57E-05	1.64E-04
Mo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Na	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ni	1.04E-05	2.75E-05	1.08E-05	2.36E-05	1.33E-05	2.40E-05	2.59E-05	6.88E-05	2.69E-05	5.90E-05	3.31E-05	6.00E-05	1.04E-05	2.75E-05	1.08E-05	2.36E-05	1.33E-05	2.40E-05
N03	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb	7.92E-05	1.02E-03	5.00E-05	2.13E-04	8.75E-05	2.71E-04	7.92E-04	1.02E-02	5.00E-04	2.13E-03	8.75E-04	2.71E-03	3.17E-04	4.08E-03	2.00E-04	8.50E-04	3.50E-04	1.08E-03
SO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Se	1.38E-03	6.06E-03	2.38E-02	3.38E-01	1.44E-03	1.23E-02	4.82E-03	2.13E-02	8.33E-02	1.18E+00	5.04E-03	4.30E-02	1.93E-03	8.51E-03	3.33E-02	4.74E-01	2.02E-03	1.72E-02
Sn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
U	3.54E-04	1.84E-03	1.16E-02	5.77E-02	1.67E-03	9.07E-03	8.84E-04	4.60E-03	2.91E-02	1.44E-01	4.18E-03	2.27E-02	3.54E-04	1.84E-03	1.16E-02	5.77E-02	1.67E-03	9.07E-03
V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn	1.46E-05	4.25E-05	1.54E-05	4.79E-05	3.08E-05	1.08E-04	1.95E-05	5.67E-05	2.05E-05	6.38E-05	4.10E-05	1.45E-04	7.80E-06	2.27E-05	8.20E-06	2.55E-05	1.64E-05	5.78E-05
K-40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-232	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.5-20. Summary of Data Quality Objectives for the Surface Water Investigation

			Inputs				
Assessment Endpoint	**Objective**	**Decisions**	**Data Input**	**Data Source**	**Data Action Levels**	**Sampling and Analytical Techniques**	**Study Boundaries**
Protection of Montezuma Creek fish populations and San Juan River endangered fish populations from deleterious effects associated with elevated concentrations of metals and radionuclides	Assess whether chemical concentrations are site-related.	Are chemical concentrations in surface water greater than background concentrations?	Surface water analytical data.	Surface water data collected from Montezuma Creek.	Significantly higher than back-ground at 80% confidence and 90% power	• **Sampling** Submersion of sample bottle and peristaltic pump • **Analysis** Section 4.5.4.3	Surface water in Montezuma Creek and associated beaver ponds downstream from historic tailings deposition.
			Surface water analytical data.	Surface water data collected from above the confluence of Montezuma Creek and Verdure Creek.		• **Sampling** Submersion of sample bottle and peristaltic pump • **Analysis** Section 4.5.4.3	Surface water at the confluence of Montezuma Creek and Verdure Creek .
			Background surface water analytical data (collocated with background biotic samples).	Surface water data collected from Verdure Creek.		• **Sampling** Submersion of sample bottle and peristaltic pump • **Analysis** Section 4.5.4.3	Surface water from the reference drainage, Verdure Creek, and associated beaver ponds .
	Assess whether chemical concentrations in surface water are toxic to aquatic receptors, excluding mammals.	**Measurement Endpoint:** Are chemical concentrations in water greater than AWQC?	Average and RME surface-water concentrations	Computed from surface water data collected from Montezuma Creek	Acute and chronic AWQC for chemicals	• **Sampling** Field Sampling Plans	Montezuma Creek downstream from historic tailings deposition , and Verdure Creek.
	Assess whether elevated metal and radionuclide concentrations in surface water of Montezuma Creek would decrease the survivability and reproductive success of aquatic receptors in Montezuma Creek and endangered fish species in the San Juan River.	Are potential impacts significant for aquatic receptors including endangered fish?	Endangered fish survey and sensitivity data for San Juan River	USFWS or Utah DEQ	ETAG consensus		San Juan River downstream from its confluence with Montezuma Creek .
			Surface-water modeling	Surface water data collected from Montezuma Creek		• Superfund Exposure Assessment Manual	San Juan River downstream from its confluence with Montezuma Creek.
Protection of muskrat populations from deleterious effects associated with elevated concentrations of metals and radionuclides	Assess whether chemical concentrations in surface water are toxic to muskrat.	**Measurement Endpoints:** Are chemical concentrations in surface water greater than TBVs?	Average and RME surface-water concentrations	Computed from data collected from Montezuma Creek	TBVs for beaver or muskrat .		

Table 4.5-20. Summary of Data Quality Objectives for the Surface Water Investigation (continued)

Assessment Endpoint	Objective	Decisions	Inputs: Data Input	Inputs: Data Source	Inputs: Data Action Levels	Inputs: Sampling and Analytical Techniques	Study Boundaries
Protection of terrestrial receptors (mule deer, deer mouse, southwestern willow-flycatcher, spotted bat, and peregrine falcon) from deleterious effects associated with elevated concentrations of metals and radionuclides.		**Measurement Endpoints:** Are chemical concentrations in surface water greater than TBVs?	Average and RME surface water concentrations	Computed from data collected from Montezuma Creek	TBVs for terrestrial receptors		

AWQC Ambient Water Quality Criteria
DEQ Department of Environmental Quality
ETAG Ecological Technical Assistance Group
RME Reasonable maximum exposure
TBV Toxicity benchmark value
USFWS U.S. Fish and Wildlife Services

Table 4.5-21. Summary of Data Quality Objectives for the Sediment Investigation

Assessment Endpoint	Objective	Decision	Inputs				Study Boundaries
			Data Input	Data Sources	Data Action Level	Sampling and Analytical Techniques	
Protection of aquatic prey species populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	Assess whether chemical concentrations are site-related	Are chemical concentrations in sediment greater than background concentrations?	Sediment analytical data	Sediment data collected from Montezuma Creek and ponds	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Hard sediment corer/auger or scoop • **Analysis** Section 4.5.4.3	Sediment from two depths in Montezuma Creek and associated beaver ponds downstream from historic tailings deposition
			Sediment analytical data	Sediment data to be collected from above the confluence of Montezuma and Verdure Creeks.		• **Sampling** Hard sediment corer/auger or scoop • **Analysis** Section 4.5.4.3	Sediment from two depths at the confluence of Montezuma and Verdure Creeks .
			Background sediment analytical data (collocated with background biotic samples)	Sediment data to be collected from Verdure Creek and ponds		• **Sampling** Hard sediment corer/auger or scoop • **Analysis** Section 4.5.4.3	Sediment from two depths from the reference drainage, Verdure Creek, and associated beaver ponds
	Assess whether chemical concentrations in sediment are toxic to aquatic receptors	**Measurement Endpoint:** Are chemical concentrations in sediment greater than available sediment criteria?	Average and RME sediment concentrations	Computed from sediment data collected from Montezuma Creek and ponds	Sediment criteria for chemicals		
			Endangered fish survey and sensitivity data for San Juan River	USFWS	ETAG consensus		San Juan River downstream from its confluence with Montezuma Creek

Table 4.5-21. Summary of Data Quality Objectives for the Sediment Investigation (continued)

Assessment Endpoint	Objective	Decision	Inputs: Data Input	Inputs: Data Sources	Inputs: Data Action Level	Inputs: Sampling and Analytical Technique	Study Boundaries
Protection of muskrat populations from deleterious effects associated with elevated concentrations of metals and radionuclides	Assess whether chemical concentrations in sediment are toxic to muskrat.	**Measurement Endpoint:** Are calculated chemical doses to receptors greater than TBVs?	Average and RME sediment concentrations for Montezuma Creek and ponds	Computed from sediment data collected from Montezuma Creek and ponds	TBVs for muskrat		

ETAG Ecological Technical Assistance Group
RME Reasonable maximum exposure
TBV Toxicity benchmark value
USFWS U.S. Fish and Wildlife Service

Table 4.5-22. Summary of Data Quality Objectives for the Soil Investigation

Assessment Endpoint	Objective	Decisions	Inputs: Data Input	Inputs: Data Source	Inputs: Data Action Levels	Inputs: Sampling and Analytical Techniques	Study Boundaries
Protection of terrestrial recepptors (mule deer and deer mouse) from deleterious effects associated with elevated concentrations of metals and radionuclides in soil.	Assess whether chemical concentrations are site-related	Are chemical concentrations in soil greater than background concentrations?	Focused study area soil analytical data	Soil data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Scoop/Auger • **Analysis** Section 4.5.4.3	Soil from Montezuma Canyon
			Background soil analytical data.	Soil data to be collected from Verdure Canyon		• **Sampling** Scoop/Auger • **Analysis** Section 4.5.4.3	Soil from Verdure Canyon
	Assess whether chemical concentrations in soil are toxic to populations of terrestrial ecological receptors	**Measurement Endpoint:** Are chemical concentrations in surface soil greater than TBVs? (Confidence = 80%; Power = 90%; MDRD ≤ 40%)	Average and RME soil concentrations	Computed from focused study area soil data.	TBVs for mule deer and deer mouse		

CV Coefficient of variation
MDRD Minimum detectable relative difference
TBV Toxicity benchmark value

Table 4.5-23. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Perennial Grasses

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
Protection of mule deer, deer mouse, and muskrat populations from deleterious effects associated with elevated concentrations of metals and radionuclides.	Assess whether chemical concentrations in collocated soil samples are site-related	Are chemical concentrations in collocated soil samples greater than background concentrations?	Soil analytical data (collocated with perennial grass samples)	Soil data collected during field seasons 1994-1995.	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Scoop/auger • **Analysis** Section 4.5.4.3	Soil in Montezuma Canyon
			Background soil analytical data (collocated with background perennial grass samples)	Data collectec from Verdure Canyon		• **Sampling** Scoop/auger • **Analysis** Section 4.5.4.3	Soil in the reference area, Verdure Canyon
	Assess whether chemical concentrations in perennial grasses are site related	Are chemical tissue concentrations significantly greater than background tissue concentrations (80% Confidence; 90% Power; MDRD ≤ 40%)?	Perennial grass tissue analytical data	Data collectec from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Clip at ground level • **Analysis** Refer to Section 4.5.4.3	Montezuma Canyon
			Background perennial grass tissue analytical data	Data collected from Verdure Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Clip at ground level • **Analysis** Section 4.5.4.3	Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Soil analytical data	Soil data collected from Montezuma Canyon	Statistical performance goals (80% Confidence; 90% Power; ≤ 40% MDRD)	Parametric or nonparametric statistics as dictated by data	
			Perennial grass tissue analytical data	Data collected from Montezuma Canyon			
	Assess whether chemical concentrations in perennial grasses result in decreased population success of mule deer, deer mouse, or muskrat.	Are chemicals bioaccumulating onsite relative to reference area?	Chemical detections in soil and perennial grasses	Soil data from Montezuma Canyon	Acceptable tissue concentrations and refence area data	Parametric or nonparametric statistics as dictated by data.	

Table 4.5-23. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Perennial Grasses (continued)

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
		Measurement Endpoint: Are modeled dietary intakes greater than TBVs?	Modeled dietary chemical intakes in herbivores	Vegetation data from Montezuma Canyon	TBVs for mule deer, deer mouse, and muskrat		
		Do elevated chemical concentrations in perennial grasses decrease population success of herbivores?	Chemical detections in perennial grasses	Vegetation data from Montezuma Canyon	TBVs for mule deer, deer mouse, and muskrat		

CV Coefficient of variation
MDRD Minimum detectable relative difference
TBV Toxicity benchmark value

Table 4.5-24. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Forbs

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
Protection of mule deer and deer mouse populations from deleterious effects associated with elevated concentrations of heavy metals and radionuclides.	Assess whether chemical concentrations in collocated soil samples are site-related	Are chemical concentrations in collocated soil samples greater than background concentrations?	Focused study area soil analytical data (collocated with forb samples)	Soil data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Scoop/auger • **Analysis** Section 4.5.4.3	Soil in Montezuma Canyon
			Background surface and subsurface soil analytical data (collocated with background shrub samples)	Data collected from Verdure Canyon		• **Sampling** Scoop • **Analysis** Section 4.5.4.3	Soil in the reference area, Verdure Canyon
	Assess whether chemical concentrations in forbs are site-related	Are chemical tissue concentrations significantly greater than background tissue concentrations (80% Confidence; 90% Power; MDRD ≤ 40%)?	Forb tissue analytical data	Data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Clip at ground level • **Analysis** Section 4.5.4.3	Montezuma Canyon
			Background forb tissue analytical data	Data collected from Verdure Canyon		• **Sampling** Clip at ground level • **Analysis** Section 4.5.4.3	Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Surface and subsurface soil analytical data	Soil data collected from Montezuma Canyon	Statistical performance goals (80% Confidence; 90% Power; MDRD ≤ 40%)	Parametric or nonparametric statistics as dictated by data	
			Forb tissue analytical data	Data collected from Montezuma Canyon			
	Assess whether chemical concentrations in forbs result in decreased population success of herbivores.	Are chemicals bioaccumulating onsite relative to the reference area?	Chemical detections in soil and forbs	Soil data from Montezuma Canyon	Acceptable tissue concentrations and reference area data	• **Analysis** Section 4.5.4.3	

Table 4.5-24. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Forbs (continued)

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
		Measurement Endpoint: Are modeled dietary intakes greater than TBVs?	Modeled dietary chemical intakes in herbivores	Vegetation data from Montezuma Canyon	TBVs for mule deer and deer mouse		
		Do elevated chemical concentrations in forbs decrease population success of herbivores?	Chemical detections in forbs	Vegetation data from Montezuma Canyon	TBVs for mule deer and deer mouse	**Analysis** Section 4.5.4.3	

CV Coefficient of variation
MDRD Minimum detectable relative difference
TBV Toxicity benchmark value

Table 4.5-25. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Shrubs

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
Protection of mule deer and muskrat populations from deleterious effects assciated with elevated concentrations of heavy metals and radionuclides.	Assess whether chemical concentrations in collocated soil samples are site-related	Are chemical concentrations in collocated soil samples greater than background concentrations?	Focused study area soil analytical data (collocated with shrub samples)	Soil data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	**Sampling** Scoop/auger **Analysis** Section 4.5.4.3	Soil in Montezuma Canyon
			Background surface and subsurface soil analytical data (collocated with background shrub samples)	Data collected from Verdure Canyon		**Sampling** Scoop **Analysis** Section 4.5.4.3	Soil in the reference area, Verdure Canyon
	Assess whether chemical concentrations in shrubs are site-related	Are chemical tissue concentrations significantly greater than background tissue concentrations (80% Confidence; 90% Power; MDRD ≤ 40%)?	Shrub tissue analytical data	Data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	**Sampling** Clip at ground level **Analysis** Section 4.5.4.3	Montezuma Canyon
			Background shrub tissue analytical data	Data collected from Verdure Canyon		**Sampling** Clip at ground level **Analysis** Section 4.5.4.3	Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Surface and subsurface soil analytical data	Soil data collected from Montezuma Canyon	Statistical performance goals (80% Confidence; 90% Power; MDRD ≤ 40%)	Parametric or nonparametric statistics as dictated by data	
			Shrub tissue analytical data	Data collected from Montezuma Canyon			
	Assess whether chemical concentrations in shrubs result in decreased population success of herbivores.	Are chemicals bioaccumulating onsite relative to the reference area?	Chemical detections in soil and shrubs	Soil data from Montezuma Canyon	Acceptable tissue concentrations and reference area data	**Analysis** Section 4.5.4.3	

Table 4.5-25. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Shrubs (continued)

Assessment Endpoint	Objective	Decision	Inputs: Data Input	Inputs: Data Sources	Inputs: Data Action Level	Inputs: Sampling and Analytical Techniques	Study Boundaries
		Measurement Endpoint: Are modeled dietary intakes greater than TBVs?	Modeled dietary chemical intakes in herbivores	Vegetation data from Montezuma Canyon	TBVs for mule deer and muskrat		
		Do elevated chemical concentrations in shrubs decrease population success of herbivores?	Chemical detections in shrubs	Vegetation data from Montezuma Canyon	TBVs for mule deer and muskrat	**Analysis** Section 4.5.4.3	

CV Coefficient of variation
MDRD Minimum detectable relative difference
TBV Toxicity benchmark value

Table 4.5-26. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Terrestrial Invertebrates

Assessment Endpoint	Objective	Decision	Inputs: Data Input	Inputs: Data Sources	Inputs: Data Action Level	Inputs: Sampling and Analytical Techniques	Study Boundaries
Protection of deer mouse populations from deleterious effects assciated with elevated concentrations of heavy metals and radionuclides.	Assess whether chemical concentrations in collocated soil samples are site-related	Are chemical concentrations in collocated soil samples greater than background concentrations?	Focused study area soil analytical data (collocated with terrestrial invertebrate samples)	Soil data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	**Sampling** Scoop/auger **Analysis** Section 4.5.4.3	Soil in Montezuma Canyon
			Background surface and subsurface soil analytical data (collocated with background terrestrial invertebrate samples)	Data collected from Verdure Canyon		**Sampling** Scoop **Analysis** Section 4.5.4.3	Soil in the reference area, Verdure Canyon
	Assess whether chemical concentrations in terrestrial invertebrates are site-related	Are chemical tissue concentrations significantly greater than background tissue concentrations (80% Confidence; 90% Power; MDRD ≤ 40%)?	Terrestrial invertebrate tissue analytical data	Data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	**Sampling** Clip at ground level **Analysis** Section 4.5.4.3	Montezuma Canyon
			Background terrestrial invertebrate tissue analytical data	Data collected from Verdure Canyon		**Sampling** Clip at ground level **Analysis** Section 4.5.4.3	Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Surface and subsurface soil analytical data	Soil data collected from Montezuma Canyon	Statistical performance goals (80% Confidence; 90% Power; MDRD ≤ 40%)	Parametric or nonparametric statistics as dictated by data	
			Terrestrial invertebrate tissue analytical data	Data collected from Montezuma Canyon			
	Assess whether chemical concentrations in terrestrial invertebrates result in decreased population success of herbivores.	Are chemicals bioaccumulating onsite relative to the reference area?	Chemical detections in soil and terrestrial invertebrates	Soil data from Montezuma Canyon	Acceptable tissue concentrations and reference area data	**Analysis** Section 4.5.4.3	

Table 4.5-26. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Terrestrial Invertebrates (continued)

Assessment Endpoint	Objective	Decision	Inputs: Data Input	Inputs: Data Sources	Inputs: Data Action Level	Inputs: Sampling and Analytical Techniques	Study Boundaries
		Measurement Endpoint: Are modeled dietary intakes greater than TBVs?	Modeled dietary chemical intakes in herbivores	Vegetation data from Montezuma Canyon	TBVs for deer mouse		
		Do elevated chemical concentrations in terrestrial invertebrates decrease population success of herbivores?	Chemical detections in terrestrial invertebrates	Vegetation data from Montezuma Canyon	TBVs for deer mouse	**Analysis** Section 4.5.4.3	

CV Coefficient of variation
MDRD Minimum detectable relative difference
TBV Toxicity benchmark value

Table 4.5-27. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Cliff Swallow as Surrogate for Western Willow Flycatcher and Spotted Bat

Assessment Endpoint	Objective	Decision	Inputs				Study Boundaries
			Data Input	Data Sources	Data Action Level	Sampling and Analytical Techniques	
Protection of southwestern willow flycatcher and spotted bat populations from deleterious effects associated with elevated concentrations of heavy metals and radionuclides.	Assess whether chemical concentrations in cliff swallow nestling tissues are site related.	Are chemical concentrations in tissue greater than background concentrations?	Focused study area cliff swallow-nestling tissue analytical data.	Data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	· Sampling Field Sampling Plan · Analysis Section 4.5.4.3	Available cliff swallow nests in Montezuma Canyon.
			Background cliff swallow-nestling tissue analytical data.	Data collected from Verdure Canyon		· Sampling Field Sampling Plan · Analysis Section 4.5.4.3	Available cliff swallow nests in Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Focused study area sediment analytical data	Data collected from Montezuma Creek	Parametric or non-parametric statistics as dictated by data distribution		Montezuma Creek and ponds
			Focused study area cliff swallow-nesting tissue analytical data	Data collected from Montezuma Canyon			
	Assess whether chemical concentrations in cliff swallow nestling tissue are indicative of impaired survivability or reproductive success of western willow flycatcher or spotted bats.	Are chemical tissue concentrations resulting in pathological changes based on histopathology?	Histopathological results for onsite tissue (liver, kidney)	Data collected from Montezuma Canyon	Comparison to the histopathological results for the reference area	· Sampling Field Sampling Plan · Analysis Section 4.5.4.3	Available cliff swallow nests in Montezuma Canyon
			Histopathological results for background tissue (liver, kidney)	Data collected from Verdure Canyon		· Sampling Field Sampling Plan · Analysis Section 4.5.4.3	Available cliff swallow nests in Verdure Canyon

Table 4.5-27. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Cliff Swallow as Surrogate for Western Willow Flycatcher and Spotted Bat (continued)

Assessment Endpoint	Objective	Decision	Inputs				Study Boundaries
			Data Input	Data Sources	Data Action Level	Sampling and Analytical Techniques	
		Do individual or combined results of the background comparison, histopathology, and ecological survey suggest impaired population success for the southwestern willow flycatcher?			ETAG consensus		
		Do individual or combined results of the background comparison and histopathology suggest impaired population success for the spotted bat?			ETAG consensus		

ETAG Ecological Technical Assistance Group

Table 4.5-28. Summary of Data Quality Objectives for the Terrestrial Biota Investigation - Cliff Swallow as Dietary Intake for the Peregrine Falcon

Assessment Endpoint	Objective	Decision	Inputs				Study Boundaries
			Data Input	Data Sources	Data Action Level	Sampling and Analytical Techniques	
Protection of peregrine falcon populations from deleterious effects associated with elevated concentrations of heavy metals or radionuclides	Assess whether chemical concentrations in cliff swallow nestlings (whole body) are site-related.	Are chemical concentrations in whole body cliff swallow nestlings greater than background concentrations?	Focused study area cliff swallow-nestling tissue analytical data	Data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Field Sampling Plan • **Analytical** Ssection 4.5.4.3	Available cliff swallow nests in Montezuma Canyon
			Background cliff swallow-nestling tissue analytical data	Data collected from Verdure Canyon		• **Sampling** Field Sampling Plan • **Analysis** Section 4.5.4.3	Available cliff swallow nests in Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Focused study area sediment analytical data	Data collected from Montezuma Creek	Parametric or non-parametric statistics as dictated by data distribution	• **Sampling** Field Sampling Plan • **Analysis** Ssection 4.5.4.3	Montezuma Creek
			Focused study area cliff swallow nesting tissue analytical data	Data collected from Montezuma Canyon			
	Assess whether chemical concentrations in cliff swallow nestlings (whole body) result in decreased survivability and population success of peregrine falcons	**Measurement Endpoint:** Are modeled dietary intakes for the peregrine falcon greater than TBVs?	Modeled dietary intake for peregrine falcons	Cliff swallow nestling tissue data	TBVs for peregrine falcons or similar taxa		

TBV Toxicity benchmark value

Table 4.5-29. Summary of Data Quality Objectives for the Aquatic Biota Investigation - Benthic Macroinvertebrates

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
Protection of aquatic prey species populations from deleterious effects assciated with elevated concentrations of heavy metals and radionuclides.	Assess whether chemical concentrations in collocated sediment and surface water samples are site-related	Are chemical concentrations in collocated sediment and surface water samples greater than background concentrations?	Focused study area sediment and surface water analytical data (collocated with benthic macroinvertebrate samples)	Soil data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Scoop/auger • **Analysis** Section 4.5.4.3	Soil in Montezuma Canyon
			Background surface and subsurface soil analytical data (collocated with background benthic macroinvertebrate samples)	Data collected from Verdure Canyon		• **Sampling** Scoop • **Analysis** Section 4.5.4.3	Soil in the reference area, Verdure Canyon
	Assess whether chemical concentrations in benthic macroinvertebrates are site-related	Are chemical tissue concentrations significantly greater than background tissue concentrations (80% Confidence; 90% Power; MDRD ≤ 40%)?	Benthic macroinvertebrate tissue analytical data	Data collected from Montezuma Canyon	Significantly higher than background at 80% confidence and 90% power	• **Sampling** Clip at ground level • **Analysis** Section 4.5.4.3	Montezuma Canyon
			Background benthic macroinvertebrate tissue analytical data	Data collected from Verdure Canyon		• **Sampling** Clip at ground level • **Analysis** Section 4.5.4.3	Verdure Canyon
		Does a correlation exist between collocated abiotic and biotic data?	Sediment and surface water analytical data	Sediment and surface water data collected from Montezuma Canyon	Statistical performance goals (80% Confidence; 90% Power; MDRD ≤ 40%)	Parametric or nonparametric statistics as dictated by data	
			Benthic macroinvertebrate tissue analytical data	Data collected from Montezuma Canyon			

Table 4.5-29. Summary of Data Quality Objectives for the Aquatic Biota Investigation - Benthic Macroinvertebrates (continued)

			Inputs				
Assessment Endpoint	**Objective**	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**
	Assess whether chemical concentrations in sediment, surface water, and benthic macroinvertebrates result in decreased population success of aquatic prey species.	Do chemical concentrations in sediment and surface water exceed toxicity benchmark values for aquatic organisms?	Chemical concentrations in sediment and surface water	Sediment and surface water data from Montezuma Canyon	Long and Morgan (1990) ER-L and ER-M values, Federal and State AWQC		
Assessment Endpoint: Protection of muskrat populations from deleterious effects associated with elevated concentrations of heavy metals and radionuclides	Assess whether chemical concentrations in sediment, surface water, and benthic invertebrates indicate that muskrat populations may be at risk	Should muskrats be sampled?	Modeled dietary chemical doses and hazard quotients for muskrats	Muskrat dose calculations	ETAG concurrence	To be determined	To be determined
			Hazard quotients for aquatic prey species	Aquatic prey species hazard quotient calculations			

CV Coefficient of variation
MDRD Minimum detectable relative difference
TBV Toxicity benchmark value

Table 4.5-37. Derivation of LOAEL and NOAEL Values for OU III COPCs and Receptors

Contaminant	Benchmark	Type	Reference	Uncertainty Factors Used for Mule Deer	Benchmark for Mule Deer	Uncertainty Factors Used for Deer Mouse	Benchmark for Deer Mouse	Uncertainty Factors Used for Spotted Bat	Benchmark for Spotted Bat
Aluminum	87 ug/l 2500 mg/kg soil	AWQC chronic Soil-55-75% survival for wood louse	ICF Kaiser 1989	0.5 class, 0.5 lc to loael, 0.5 loael to noael	312.5	0.5 class, 0.5 lc to loael, 0.5 loael to noael	312.5	0.5 class, 0.5 lc to loael, 0.5 loael to noael	312.5
Arsenic	190 ug/l 33 ppm 300 mg/kg bw 22.5 mg/kg bw	AWQC chronic ER-L, sediment LOAEL mallard LOAEL rat	 Long and Morgan 1992 Whitworth et al 1991 Schroeder et al 1968	0.5 loael to noael	11.25 mg/kg bw	0.5 loael to noael	11.25 mg/kg bw	0.5 loael to noael	11.25 mg/kg bw
Cobalt	6171 mg/kg bw	LD50 rat	J Am Coll Tox 1:686, 1992	0.5 ld50 to loael, 0.5 loael to noael	1542.75	0.5 ld50 to loael, 0.5 loael to noael	1542.75	0.5 ld50 to loael, 0.5 loael to noael	1542.75
Copper	1000 ug/l 390 ppm 22.8 mg/kg bw 36 mg/kg bw	AWQC chronic ER-L sediment NOAEL chicken LOAEL rat	 Long and Morgan 1992 Opresko et al 1993 Suttie and Mills 1966	0.5 loael to noael	18 mg/kg bw	0.5 loael to noael	18 mg/kg bw	0.5 loael to noael	18 mg/kg bw
Molybdenum	2400 ppm 333 mg/kg bw	NOAEL bluegill (water) LD50 rat	OHM-TADS 1995 OHM-TADS 1995	0.5 ld50 to loael, 0.5 loael to noael	83.25	0.5 ld50 to loael, 0.5 loael to noael	83.25	0.5 ld50 to loael, 0.5 loael to noael	83.25 mg/kg bw
Nitrate	507 mg/kg bw	NOAEL guinae pig	Sleight & Atallah 1968	N/A	507 mg/kg bw	N/A	507 mg/kg bw	N/A	507 mg/kg bw
Selenium	5 ug/l 7600 mg/kg bw	AWQC chronic LD50 rat, oral	Tox. and Applied Pharm. 20:89, 1971	0.5 ld50 to loael, 0.5 loael to noael	1900	0.5 ld50 to loael, 0.5 loael to noael	1900	0.5 ld50 to loael, 0.5 loael to noael	1900
Sodium	4720 mg/l 4 g/kg bw	NOAEL stickleback LD50 rat, intraperitoneal	OHM-TADS 1995 Bovet and Bovet-Nitti, 1948	0.5 ld50 to loael, 0.5 loael to noeal	1000	0.5 ld50 to loael, 0.5 loael to noeal	1000	0.5 ld50 to loael, 0.5 loael to noeal	1000
Sulfate	no data								
Tin	no data								
Vanadium	23 mg/kg bw	LOAEL rat	Zaporowska et al 1989	0.5 loael to noael	11.5	0.5 loael to noael	11.5	0.5 loael to noael	11.5
Zinc	110 ug/L 120 ppm 75 mg/kg bw	AWQC chronic ER-L sediment NOAEL rat	 Long and Morgan 1992 Sutton and Nelson 1937, Lewis et al 195	N/A	75 mg/kg bw	N/A	75 mg/kg bw	N/A	75 mg/kg bw

Table 4.5-37. Derivation of LOAEL and NOAEL Values for OU III COPCs and Receptors (continued)

Contaminant	Benchmark	Type	Reference	Uncertainty Factors Used for SW Willow Flycatcher	Benchmark for SW Willow Flycatcher	Uncertainty Factors Used for Peregrine Falcon	Benchmark for Peregrine Falcon	Uncertainty Factors Used for Fish	Benchmark for Fish
Aluminum	87 ug/l 2500 mg/kg soil	AWQC chronic Soil-55-75% survival for wood louse	ICF Kaiser 1989	0.5 class, 0.5 lc to loael, 0.5 loael to noael	312.5	0.5 class, 0.5 lc to loael, 0.5 loael to noael	312.5	N/A	87 ug/l
Arsenic	190 ug/l 33 ppm 300 mg/kg bw 22.5 mg/kg bw	AWQC chronic ER-L, sediment LOAEL mallard LOAEL rat	 Long and Morgan 1992 Whitworth et al 1991 Schroeder et al 1968	0.5 loael to noael	150 mg/kg bw	0.5 loael to noael	150 mg/kg bw	N/A N/A	190 ug/l 33 ppm sed
Cobalt	6171 mg/kg bw	LD50 rat	J Am Coll Tox 1:686, 1992	.5 class, 0.5 ld50 to loael, 0. 5 loael to noa	771.375	.5 class, 0.5 ld50 to loael, 0.5 loael to noae	771.375		
Copper	1000 ug/l 390 ppm 22.8 mg/kg bw 36 mg/kg bw	AWQC chronic ER-L sediment NOAEL chicken LOAEL rat	 Long and Morgan 1992 Opresko et al 1993 Suttie and Mills 1966	N/A	22.8 mg/kg bw	N/A	22.8 mg/kg bw	N/A N/A	1000 ug/l 390 ppm sed
Molybdenum	2400 ppm 333 mg/kg bw	NOAEL bluegill (water) LD50 rat	OHM-TADS 1995 OHM-TADS 1995	.5 class, 0.5 ld50 to loael, 0.5 loael to noae	41.625	.1 class, 0.1 ld50 to loael, 0.1 loael to noae	41.625 mg/kg bw	N/A	2400 ppm water
Nitrate	507 mg/kg bw	NOAEL guinae pig	Sleight & Atallah 1968	0.5 class	253.5	0.5 class	253.5		
Selenium	5 ug/l 7600 mg/kg bw	AWQC chronic LD50 rat, oral	 Tox. and Applied Pharm. 20:89, 1971	.5 class, 0.5 ld50 to loael, 0.5 loael to noae	950	.5 class, 0.5 ld50 to loael, 0.5 loael to noae	950	N/A	5 ug/l water
Sodium	4720 mg/l 4 g/kg bw	NOAEL stickleback LD50 rat, intraperitoneal	OHM-TADS 1995 Bovet and Bovet-Nitti, 1948	.5 class, 0.5 ld50 to loael, 0.5 loael to noea	500	.5 class, 0.5 ld50 to loael, 0.5 loael to noea	500	N/A	4720 mg/l water
Sulfate	no data								
Tin	no data								
Vanadium	23 mg/kg bw	LOAEL rat	Zaporowska et al 1989	0.5 class, 0.5 loael to noael	5.75	0.5 class, 0.5 loael to noael	5.75		
Zinc	110 ug/L 120 ppm 75 mg/kg bw	AWQC chronic ER-L sediment NOAEL rat	 Long and Morgan 1992 Sutton and Nelson 1937, Lewis et al 195	0.5 class	37.5	0.5 class	37.5 mg/kg bw	N/A N/A	110 ug/L water 120 ppm sed

Table 4.6-4. Comparison of Benchmarks - Upper Flow Ground-Water System[1]

Compound	Regulatory Benchmarks: Federal SDWA MCL ug/l	Regulatory Benchmarks: State of Utah Ground Water Quality Standard ug/l	Risk Benchmark Carcinogenic & Systemic: Computed Human Health[2] ug/l	Risk Benchmark Carcinogenic & Systemic: EPA Region 3, RBCs[3] ug/l	Compound	Upper Flow Sysem Monitoring Summary - Since November 1992: Upgradient Maximum ug/l	Upgradient Arith. Mean ug/l	Millsite Maximum ug/l	Millsite Arith. Mean ug/l	Downgradient Maximum ug/l	Downgradient Arith. Mean ug/l
Aluminum					Aluminum	3920	990.79	9670	1332.36	108000	3039.2
Antimony	6		10	15	Antimony	2	1.04	1.4	1.2	1.9	0.69
Arsenic#	50	50	0.05 to 5.0	0.038 to 3.8	Arsenic	5	1.99	469	76.13	131	14.06
Barium	2000	2000	2560	2600	Barium	147	66.94	286	53.12	2250	97.09
Beryllium#	4		0.02 to 2.0	0.016 to 1.6	Beryllium	1.1	0.55	non detect	non detect	6.2	0.73
Boron				3300	Boron	107	59.94	439	159.92	544	131.5
Calcium					Calcium	517000	263911.1	606000	287419.99	408000	262058.33
Cadmium	5	5	20	18	Cadmium	non detect	non detect	3.2	0.63	2	0.54
Cobalt				2200	Cobalt	non detect	non detect	24.9	7.87	61.2	8.68
Chromium	100	100	180	180	Chromium	10.6	2.96	14	3.61	79.7	4.35
Copper		1,300	1350	1400	Copper	8.1	2.08	465	30.42	197	8.89
Lead		15	104		Lead	11.3	2.43	52.8	4.64	89.1	3.9
Manganese			180	180	Manganese	520	96.22	12900	4118.68	11400	785.29
Mercury	2	2	10	11	Mercury	non detect	non detect	non detect	non detect	non detect	non detect
Molybdenum				180	Molybdenum	3.8	5.58	2150	472.71	240	87.21
Nitrate	44000*	44000*		58000	Nitrate	20900	3863.81	286000	38338.24	53700	14052.92
Nickel	100		730	730	Nickel	non detect	non detect	63.1	14	130	9.45
Selenium	50	50	180	180	Selenium	5.1	2.84	302	30.87	57.4	15.59
Silver		100	180	180	Silver	non detect	non detect	6.7	2.19	non detect	non detect
Sulfate					Sulfate	120000	545699.99	238000	295116.66	132000	789266.86
Thallium	2		3	3	Thallium	non detect	non detect	1.1	0.59	1.8	0.62
Uranium	20			110	Uranium	7.3	4.86	12600	2072.34	2870	816.67
Vanadium			260	260	Vanadium	8.8	3.43	169000	13403.17	2890	348.2
Zinc		5000	10950	11000	Zinc	40.5	15.22	78.7	18.38	500	22.13
Pb-210#			0.07 to 7.0 pCi/l		Pb-210#	non detect	non detect	79	14.1	21	6.42
Po-210#			0.32 to 32 pCi/l		Po-210#	non detect	non detect	20.27	2.49	6.9	0.4
Ra-226#	20 pCi/l	5 pCi/l**	0.4 to 40 pCi/l		Ra-226#	0.56	0.18	16.14	2.06	1.1	0.13
Ra-228#	20 pCi/l	5 pCi/l**	0.48 to 48 pCi/l		Ra-228#	non detect	non detect	non detect	non detect	non detect	non detect
Rn-222#	300pCi/L		28.01 to 2801 pCi/l		Rn-222#	1265	700.44	59651	4302.12	10591	1577.68
Th-230#			3.66 to 366 pCi/l		Th-230#	0.45	0.11	1.06	0.51	0.91	0.49
Th-232#			3.97 to 397 pCi/l		Th-232#	0.55	0.09	0.88	0.33	0.16	0.38
U-234#			2.98 to 298 pCi/l		U-234#	77.5	7.31	4096.4	686.33	968.26	272.23
U-235#			2.98 to 298 pCi/l		U-235#	0.49	0.11	194.37	45.29	41.32	13.27
U-238#			2.38 to 238 pCi/l		U-238#	77.53	5.86	4288.8	700.13	985.64	276.33
Gross Alpha	15 pCi/l	15 pCi/l			Gross Alpha	non detect	non detect	9780	1524.4	2300	586.78
Gross Beta	50 pCi/l				Gross Beta	non detect	non detect	3300	494.25	1040	220.43

[1] Shaded values indicate an exceedance of at least one regulatory or risk-based benchmark

[2] Computed human health benchmarks based on domestic consumption, HQ = 1.0 for noncarcinogenic substances

[3] EPA Region 3 Risk Based Concentration (RBCs), fourth quarter 1994 (EPA 1994c)

* Derived from water-quality standard for nitrogen

** Limit is 5 pCi/L for Ra-226 and Ra-228 combined

Potentially carcinogenic substance; benchmarks reflect 1 E-6 to 1E-4 risk range

Table 4.6-5. Comparison of Benchmarks - Montezuma Creek and Seeps [1]

Compound	Regulatory Benchmarks			Human Health Risk **	Montezuma Creek Monitoring Summary - Since November 1992					
	Federal SDWA MCL	State of Utah				Upgradient	On site ##		Downgradient	
		Domestic	Agriculture			Maximum	Arith. Mean	Maximum	Arith. Mean	Maximum	Arith. Mean
	ug/l	ug/l	ug/l	ug/l		ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
Aluminum					Aluminum	1450	433	1360	443	3550	1007
Antimony	6			11000	Antimony	2	0.8	2.2	0.8	1.9	0.7
Arsenic #	50	50	100	37 to 3700	Arsenic #	11	4.4	1250	139.6	15.1	2.8
Barium	2000	1000		1965000	Barium	141	83.9	117	56.1	103	64.4
Beryllium #	4			15 to 1500	Beryllium #	non detect	non detect	non detect	non detect	non detect	non detect
Boron					Boron	140	69.21	403	133.22	130	73.29
Calcium					Calcium	431000	165292.4	358000	202310	324000	146986
Cadmium	5	10	10	14000	Cadmium	non detect	non detect	non detect	non detect	non detect	non detect
Cobalt					Cobalt	6.6	6.6	non detect	non detect	non detect	non detect
Chromium	100	50	100	140000	Chromium	4.9	4.9	non detect	non detect	26.3	5.1
Copper			200	1039000	Copper	10.1	10.1	65.1	6.4	10.7	2.5
Lead		50	100	20000	Lead	24.5	1.9	5.1	1.2	6.5	2.1
Manganese				3931000	Manganese	1000	266	785	167.6	460	183.9
Mercury	2	2		8400	Mercury	non detect	non detect	0.2	0.2	non detect	non detect
Molybdenum					Molybdenum	20.2	10	2450	175	90.9	13.9
Nitrate	44000*	44000*		44000	Nitrate	24600	4337.3	18500	5520.47	6190	746.99
Nickel	100			5615000	Nickel	13.3	5	11.4	5.2	11.6	6.4
Selenium	50	10	50	140380	Selenium	9.7	2.2	540	38	19.6	2.3
Silver		50		140000	Silver	non detect	non detect	non detect	non detect	non detect	non detect
Sulfate					Sulfate	100000	223611.9	138000	600493.33	787000	385105.55
Thallium	2			2250	Thallium	non detect	non detect	non detect	non detect	non detect	non detect
Uranium	20	30 pCi/l	(92 ug/l) @		Uranium	103	19.8	3230	652.1	505	93.6
Vanadium				197000	Vanadium	29.8	9.3	52000	3856.3	280	20.8
Zinc				8423000	Zinc	34	11.7	38.3	12.3	86.7	24.6
Pb-210#				56 to 5600 pCi/l	Pb-210#	non detect	non detect	33.8	5.48	2.7	1.17
Po-210#				244 to 24400 pCi/l	Po-210#	0.19	0.12	0.65	0.18	non detect	non detect
Ra-226#	20 pCi/l*	5 pCi/l*		305 to 30500 pCi/l	Ra-226#	2.4	0.6	9.1	2.4	1.3	0.3
Ra-228#	20 pCi/l*	5 pCi/l*		366 to 36600 pCi/l	Ra-228#	non detect	non detect	non detect	non detect	non detect	non detect
Rn-222#	300 pCi/L			21547 to 2154700 pCi/l	Rn-222#						
Th-230#				2818 to 281800 pCi/l	Th-230#	0.2	0.07	0.81	0.54	0.58	0.12
Th-232#				3053 to 305300 pCi/l	Th-232#	0.09	0.06	non detect	non detect		
U-234#				2289 to 228900 pCi/l	U-234#	39.3	8.3	1064.7	228.3	176.5	33.9
U-235#				2289 to 228900 pCi/l	U-235#	0.09	0.08	42.9	10.6	4.9	1.1
U-238#				1832 to 183200 pCi/l	U-238#	38.1	6.9	1063.5	228.4	174.2	33.5
Gross Alpha	15 pCi/l	15 pCi/l	15 pCi/l		Gross Alpha	60	20.2	1900	369.8	350	68.73
Gross Beta	50 pCi/l	50 pCi/l	50 pCi/l		Gross Beta	26.5	16.6	1164	164.4	130	25.8

[1] Shaded values indicate an exceedance of at least one regulatory or risk-based benchmark

* Derived from water-quality standard for nitrogen

** Benchmarks for a recreational exposure scenario: 7 days/year, 0.5 liter ingested/day, for 30 years; benchmarks reflect 1 E-6 to 1 E-4 risk range; HQ = 10

On site data includes some seeps that are not in the main Montezuma Creek channel

Potentially carcinogenic substance

@ Specific for Montezuma Creek

Table 4.6-9. Summary of Data Quality Objectives for the Upper Ground-Water Flow System Investigation - Human Health Risk Assessment

	Inputs						
Objective	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**	**Decision Errors**
Assess whether current and future conditions associated with the upper ground-water flow-system present unacceptable risk for potential human receptors. Assess whether current and future conditions associated with the upper ground-water flow system present regulatory impacts.	Are chemical concentrations in onsite ground water greater than background concentrations? Is future potential carcinogenic risk within an acceptable risk range? Is future potential noncarcinogenic risk within an acceptable range? Are future potential radiological effective does equivalents within acceptable ranges? Do future estimated COC concentrations exceed chemical specific ARARs?	Ground-water analytical data Future land use, water supply requirements, and planned water supply access determination for ground-water regions affected by the upper flow system. Future upper flow system ground-water concentration versus time profiles for COCs following remediation of OU 1.	Existing ground-water monitoring data for onsite wells completed in the upper flow-system New ground-water monitoring data for onsite wells completed in the upper flow system. New and existing background ground-water data for upgradient wells completed in the upper flow system. City of Monticello and San Juan County planning and zoning authorities, water control boards and municipal planners. Results of ground-water flow and solute transport modeling using existing and new ground-water monitoring data. Modeling results and uncertainties will generally accommodate industry standards as discussed in IAEA, 1989. Target accuracy in accordance with Table 4.7-7 approach.	The background comparison is discussed in Appendix E. Preliminary human health benchmark concentrations in Tables 4.6-2 and 4.6-3 as an initial screening assessment point. The BRA will provide a multimedia integrated assessment of risk including evaluation of the magnitude of uncertainties as the definitive finding of risk according to the NCP (Section 300.430) (EPA, 1990). Site-specific regulatory ARARs as determined under the NCP (Section 300.400 [numerous sections]) (EPA, 1990). Dose limits established under DOE Order 5400.5 of 100 *mrem*/year (DOE, 1989).	Existing on-site and background ground-water analytical data are presented in Appendix E. New onsite ground-water sampling methods, analytes, and detection limits are presented in Sections 4.6.4.3 and 4.6.4.4. Benchmark calculations are explained in Section 4.6.3.1. Ground-water modeling is discussed in Section 4.7.	Spatial: The upper flow system underlying the approximate area east of Highway 191, across the MMTS and proceeding east to where the canyon narrows. Temporal: 50 years from the time OU 1 is remediated.	Modeling results should attain target guidelines for the base-case setting. Target Range: Lower measured / 3.33 Upper measured * 3.33 Exposure factor combinations will span no more than a factor of 10. Radionuclide and inorganic risks segregated owing to different CSF derivations (Radionuclides are maximum likelihood estimates, inorganics are upper bound estimates). Uncertainties to be fully explained. Major sources to be assessed quantitatively with Monte-Carlo analysis. Analytical results assessed by QAPjP protocols. Data usability assessed by Data Usability in Risk Assessment (EPA, 1990b).

ARARs	Applicable or relevant and appropriate requirements
BRA	Baseline risk assessment
COC	Chemical of concern
CSF	Cancer slope factor
DOE	Department of Energy
EPA	Environmental Protection Agency
IAEA	International Atomic Energy Agency
MMTS	Monticello Mill Site Tailings
NCP	National Contingency Plan
OU	Operable unit
QUAPjP	Quality Assurance Project Plan
RME	Reasonable maximum exposure

Table 4.6-10. Summary of Data Quality Objectives for the Surface Water Investigation - Human Health Risk Assessment

		Inputs					
Objective	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**	**Decision Errors**
Assess whether current and future conditions present unacceptable risk for potential human receptors. Assess whether current and future conditions associated with the surface water of Montezuma Creek exceed regulatory requirements.	Are chemical concentrations in onsite surface water greater than background concentrations? Is future potential carcinogenic risk within an acceptable risk range? Is future potential noncarcinogenic risk within an acceptable range? Are future potential radiological effective dose equivalents within acceptable ranges? Do future estimated COC concentrations exceed chemical specific ARARs?	Surface water analytical data. Future land use, water supply requirements, and planned water supply access determination for Montezuma Creek. Future Montezuma Creek concentration versus time profiles for COCs following remediation of OU 1. Montezuma Creek chemistry, flow, and watershed hydrology as input to the model.	Existing surface water data for Montezuma Creek. New surface water data for Montezuma Creek. New and existing background surface water data for upstream locations on Montezuma Creek. City of Monticello and San Juan County planning and zoning authorities, water control boards and municipal planners. Ground-water flow and solute transport modeling results and uncertainties will generally accommodate industry standards as discussed in IAEA, 1989. Target accuracy should be within approximately a factor of 3 of the measured range endpoints to be consistent with human health risk uncertainties. Ongoing monitoring program may require modification after initial modeling results are evaluated.	The background comparison is discussed in Appendix B. Preliminary human health benchmark concentrations in Tables 4.6-2 and 4.6-3 as an initial screening assessment point. The BRA will provide a multimedia integrated assessment of risk including evaluation of the magnitude of uncertainties as the definitive finding of risk according to the NCP (Section 300.430) (EPA, 1990). Site-specific regulatory ARARs as determined under the NCP (Section 300.430) (EPA, 1990). Dose limits established under DOE Order 5400.5 of 100 mrem/year (DOE, 1989).	New onsite and background sampling methods, analytes, and detection limits are presented in Sections 4.6.4.3 and 4.6.4.4. Benchmark calculations are explained in Section 4.6.3.1. Ground-water modeling is discussed in Section 4.7.	Spatial: The reach of Montezuma Creek from Highway 191 to approximately 0.5 mile below the confluence of Vega Creek. Temporal: 50 years from the time OU 1 is remediated.	Exposure factor combinations will span no more than a factor of 10. Radionuclide and inorganic risks segregated owing to different CSF derivations (Radionuclides are maximum likelihood estimates, inorganics are upper bound estimates). Uncertainties to be fully explained. Major sources to be assessed quantitatively with Monte-Carlo analysis. Analytical results assessed by QAPjP protocols. Data usability assessed by Data Usability in Risk Assessment (EPA, 1990b).

ARAR	Applicable or relevant and appropriate requirements
BRA	Baseline risk assessment
COC	Chemical of concern
DOE	Department of Energy
EPA	Environmental Protection Agency
IAEC	International Atomic Energy Agency
NCP	National Contingency Plan
OU	Operable unit

Table 4.6-11. Summary of Data Quality Objectives for the Sediment Investigation - Human Health Risk Assessment

		Inputs					
Objective	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**	**Decision Errors**
Assess whether current and future conditions associated with the sediment of Montezuma Creek present unacceptable risk for potential human receptors.	Are chemical concentrations in onsite sediment greater than background concentrations? Is future potential carcinogenic risk within an acceptable risk range? Is future potential noncarcinogenic risk within an acceptable range? Are future potential radiological effective dose equivalents within acceptable ranges.	Sediment analytical data. Future land use, water supply requirements and planned water supply access determination for Montezuma Creek.	Existing sediment data for Montezuma Creek. New sediment data for Montezuma Creek. City of Monticello and San Juan County planning and zoning authorities, water control boards, and municipal planners. New background sediment data from Verdure Canyon.	The background comparison is discussed in Section Appendix E. Preliminary human health benchmark concentrations in Tables 4.6-2 and 4.6-3 as an initial screening assessment point. The BRA will provide a multimedia integrated assessment of risk including evaluation of the magnitude of uncertainties as the definitive finding of risk according to the NCP (Section 300.430) (EPA, 1990). Dose limits established under DOE Order 5400.5 of 100 mrem/year (DOE, 1989).	Existing focused study area sediment analytical data are presented in Appendix E. New on-site and background sampling methods, analytes, and detection limits are presented in Sections 4.6.4.3 and 4.6.4.4. Benchmark calculations are presented in Section 4.6.3.1.	Spatial: The reach of Montezuma Creek from Highway 191 to approximately 0.5 mile below the confluence of Vega Creek. Temporal: 50 years from the time OU 1 is remediated.	Exposure factor combinations will span no more than a factor of 10. Radionuclide and inorganic risks segregated owing to different CSF derivations (Radionuclides are maximum likelihood estimates, inorganics are upper bound estimates). Uncertainties to be fully explained. Major sources to be assessed quantitatively with Monte-Carlo analysis. Analytical results assessed by QAPjP protocols. Data usability assessed by Data Usability in Risk Assessment (EPA, 1990b).

ARAR	Applicable or relevant and appropriate requirements
BRA	Baseline risk assessment
COC	Chemical of concern
DOE	Department of Energy
EPA	Environmental Protection Agency
IAEC	International Atomic Energy Agency
NCP	National Contingency Plan
OU	Operable unit

Table 4.6-12. Summary of Data Quality Objectives for the Soil Investigation - Human Health Risk Assessment

		Inputs					
Objective	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**	**Decision Errors**
Assess whether current and future conditions associated with the soil of Montezuma Canyon present unacceptable risks for human receptors.	Are chemical concentrations in onsite soil greater than background concentrations? Is future potential carcinogenic risk within an acceptable range? Is future potential noncarcinogenic risks within an acceptable range? Are future potential radiological effective dose equivalents within acceptable ranges?	Soil analytical data. Future land use in Montezuma Canyon.	Existing soil data for Montezuma Canyon. New soil data for Montezuma Canyon. New background data from Verdure Canyon. City of Monticello and San Juan County planning and zoning authorities, water control boards and municipal planners.	The background comparison is discussed in Appendix E. Preliminary human health benchmark concentrations in Tables 4.6-2 and 4.6-3 as an initial screening assessment point. The BRA will provide a multimedia integrated assessment of risk including evaluation of the magnitude of uncertainties as the definitive finding of risk according to the NCP (Section 300.430) (EPA, 1990). Dose limits established under DOE Order 5400.5 of 100 mrem/year (DOE, 1989).	Existing focused study area soil data are presented in Appendix E. New onsite and background sampling methods, analytes, and detection limits are presented in Sections 4.6.4.3 and 4.6.4.4. Benchmark calculations are explained in Section 4.6.3.1.	Spatial: Onsite refers to Montezuma Canyon as shown on Figure 1.0-3. Background refers to Verdure Canyon as shown on Figure 4.5-5.	Exposure factor combinations will span no more than a factor of 10. Radionuclide and inorganic risks segregated owing to different CSF derivations (Radionuclides are maximum likelihood estimates, inorganics are upper bound estimates). Uncertainties to be fully explained. Major sources to be assessed quantitatively with Monte-Carlo analysis. Analytical results assessed by QAPjP protocols. Data usability assessed by Data Usability in Risk Assessment (EPA, 1990b).

ARAR	Applicable or relevant and appropriate requirements
BRA	Baseline risk assessment
COC	Chemical of concern
DOE	Department of Energy
EPA	Environmental Protection Agency
IAEC	International Atomic Energy Agency
NCP	National Contingency Plan
OU	Operable unit

Table 4.6-13. Summary of Data Quality Objectives for the Biota Investigation - Human Health Risk Assessment

		Inputs					
Objective	**Decision**	**Data Input**	**Data Sources**	**Data Action Level**	**Sampling and Analytical Techniques**	**Study Boundaries**	**Decision Errors**
Assess whether current or future conditions associated with cattle that graze in Montezuma Canyon present unacceptable risk for potential human receptors.	Are chemical tissue concentrations in onsite cattle that graze in Montezuma Canyon greater than background concentrations? Is future potential carcinogenic risk within an acceptable risk range? Is future potential noncarcinogenic risk within an acceptable range? Are future radiological effective dose equivalents within acceptable ranges?	Calf tissue (muscle and liver) analytical data. Future agricultural land use in Montezuma Canyon.	New calf tissue data from calves grazed in Montezuma Canyon for one season. New calf tissue data from calves grazed in Verdure Canyon for one season. City of Monticello and San Juan County planning and zoning authorities, water control boards, and municipal planners.	The BRA will provide a multimedia integrated assessment of risk including evaluation of the magnitude of uncertainties as the definitive finding of risk according to the NCP (Section 300.430) (EPA, 1990). Dose limits established under DOE Order 5400.5 of 100 mrem/year (DOE, 1989).	On-site and background tissue sampling methods, analytes, and detection limits are presented in Sections 4.6.4.3 and 4.6.4.4.	Spatial: Onsite refers to Montezuma Canyon as shown on Figure 1.0-3. Background refers to Verdure Canyon as shown on Figure 4.5-5.	Exposure factor combinations will span no more than a factor of 10. Radionuclide and inorganic risks segregated owing to different CSF derivations (Radionuclides are maximum likelihood estimates, inorganics are upper bound estimates). Uncertainties to be fully explained. Major sources to be assessed quantitatively with Monte-Carlo analysis. Analytical results assessed by QAPjP protocols. Data usability assessed by Data Usability in Risk Assessment (EPA, 1990b).

ARAR	Applicable or relevant and appropriate requirements
BRA	Baseline risk assessment
COC	Chemical of concern
DOE	Department of Energy
EPA	Environmental Protection Agency
IAEC	International Atomic Energy Agency
NCP	National Contingency Plan
OU	Operable unit

Table 4.8-2. Analytes, Analytical Methods, and Method Detection Limits for Ground-Water Samples and Surface-Water Samples, OU III Annual Monitoring Task.

Analytical Parameter	Method Detection Limit	Analytical Method
Metals[a]	(µg/L)	
Aluminum	50	CLP Method 200.7
Arsenic	5.0	EPA SW-846 6020
Cobalt	10.0	CLP Method 200.7
Copper	5.0	CLP Method 200.7
Manganese	5.0	CLP Method 200.7
Molybdenum	50	CLP Method 200.7
Selenium	5.0	EPA SW-846 6020
Tin	5.0	EPA SW-846 6020
Uranium	NA[b]	Not Applicable[b]
Vanadium	10.0	CLP Method 200.7
Zinc	4.0	CLP Method 200.7
Total Dissolved Solids (filterable residue)	10,000	EPA Method 160.1
Major Anions		
Chloride	200	EPA Method 300
Sulfate	200	
Fluoride	200	
Nitrate (NO_3 + NO_2 as N)	200	
Nitrite	200	
Major Cations		
Ammonia	20	EPA Method 350.1
Calcium	100	CLP Method 200.7
Magnesium	100	
Potassium	700	
Sodium	600	
Radionuclides	(pCi/L)	
Lead-210	2.0	Geotech Method RC-6
Polonium-210	0.5	Geotech Method RC-2
Radium-226	0.5	Geotech Method RC-5
Radon-222	60	Geotech Method RC-17
Thorium-230	1.0	EPA SW-846 6020[c]
Uranium-234, Uranium-235, and Uranium-238	1.0	EPA SW-846 6020[c]
Gross Alpha Activity	1.0	Geotech Method RC-3
Gross Beta Activity	1.0	Geotech Method RC-3

[a] Total and dissolved metals fractions for surface water samples; total metals fraction for ground-water samples.
[b] Uranium isotopes will be measured rather than total uranium, which is approximately 99.3% U-238.
[c] Method 6020 as modified by GJPO Analytical Laboratory for analysis of these radionuclides.

Table 4.8-2. Analytes, Analytical Methods, and Method Detection Limits for Ground-Water Samples and Surface-Water Samples, OU III Annual Monitoring Task. (continued)

Analytical Parameter	Method Detection Limit	Analytical Method
Volatile Organic Compounds (Target Compound List)	(µg/L)	
Acetone	2	EPA Method 8260
Benzene	1	
Bromodichloromethane	1	
Bromoform	1	
Bromomethane	2	
2-Butanone	2	
Carbon disulfide	1	
Carbon tetrachloride	1	
Chlorobenzene	1	
Chlorodibromomethane	1	
Chloroethane	2	
Chloroform	1	
Chloromethane	2	
1,1-Dichloroethane	1	
1,2-Dichloroethane	1	
1,1-Dichloroethene	1	
trans-1,2-Dichloroethene	1	
	1	
1,2-Dichloropropane	1	
cis-1,3-Dichloropropene	1	
trans-1,3-Dichloropropene	1	
	2	
Ethyl benzene	1	
2-Hexanone	2	
Methylene chloride	1	
4-Methyl-2-pentanone	1	
Styrene	1	
1,1,2,2-Tetrachloroethane	1	
	1	
Tetrachloroethene	1	
Toluene	1	
1,1,1-Trichloroethane	2	
1,1,2-Trichloroethane	2	
Trichloroethene	1	
Vinyl acetate		
Vinyl chloride		
Xylene		

Table 4.8-2. Analytes, Analytical Methods, and Method Detection Limits for Ground-Water Samples and Surface-Water Samples, OU III Annual Monitoring Task. (Continued)

Analytical Parameters	Method Detection Limit	Analytical Method
Semi-Volatile Organic Compounds (Target Compound List)	(µg/L)	EPA Method 8270
	10	
Acenaphthene	10	
Acenaphthylene	10	
Anthracene	10	
Benzo(a)anthracene	10	
Benzo(b)fluoranthene	10	
Benzo(k)fluoranthene	10	
Benzo(g,h,i)perylene	10	
Benzo(a)pyrene	10	
Bis(2-chloroethoxy)methane	10	
Bis(2-chloroethyl)ether	10	
2,2'-Oxybis (1-chloropropane)	10	
Bis(2-ethylhexyl)phthalate	10	
4-Bromophenyl phenylether	10	
Butyl benzyl phthalate	10	
Carbozole	10	
4-Chloroaniline	10	
2-Chloronaphthalene	10	
4-Chloro-3-methylphenol	10	
2-Chlorophenol	10	
4-Chlorophenyl phenyl ether	10	
Chrysene	10	
Dibenz(a,h)anthracene	10	
Dibenzofuran	10	
Di-n-butylphthalate	10	
1,2-Dichlorobenzene	10	
1,3-Dichlorobenzene	10	
1,4-Dichlorobenzene	20	
3,3'-Dichlorobenzidine	10	
2,4-Dichlorophenol	10	
Diethylphthalate	10	
2,4-Dimethylphenol	10	
Dimethylphthalate	50	
4,6-Dinitro-2-methylphenol	50	
2,4-Dinitrophenol	10	
2,4-Dinitrotoluene	10	
2,6-Dinitrotoluene	10	
Di-n-octylphthalate	10	
Fluoranthene	10	
Fluorene	10	
Hexachlorobenzene	10	
Hexachlorobutadiene	10	
Hexachlorocyclopentadiene	10	
Hexachloroethane	10	
Indeno(1,2,3-cd)pyrene		

Table 4.8-2. Analytes, Analytical Methods, and Method Detection Limits for Ground-Water Samples and Surface-Water Samples, OU III Annual Monitoring Task. (Continued)

Analytical Parameter	Method Detection Limit	Analytical Method
Semi-Volatile Organic Compounds (Target Compound List) (continued)	(µg/L)	EPA Method 8270
	10	
Isophorone	10	
2-Methylnaphthalene	10	
2-Methylphenol	10	
4-Methylphenol	10	
Naphthalene	50	
2-Nitroaniline	50	
3-Nitroaniline	50	
4-Nitroaniline	10	
Nitrobenzene	10	
2-Nitrophenol	50	
4-Nitrophenol	10	
N-Nitroso-di-n-dipropylamine	10	
	50	
N-Nitrosodiphenylamine	10	
Pentachlorophenol	10	
Phenanthrene	10	
Phenol	10	
Pyrene	50	
1,2,4-Trichlorobenzene	10	
2,4,5-Trichlorophenol		
2,4,6-Trichlorophenol		
		EPA Method 8080
Pesticides/PCBs	0.05	
	0.05	
Aldrin	0.05	
Alpha-BHC	0.05	
Beta-BHC	0.05	
Delta-BHC	0.05	
Gamma-BHC (lindane)	0.05	
Alpha-Chlordane	0.10	
Gamma-Chlordane	0.10	
4,4'-DDD	0.10	
4,4'-DDE	0.10	
4,4'-DDT	0.05	
Dieldrin	0.10	
Endosulfan I	0.10	
Endosulfan II	0.10	
Endosulfan Sulfate	0.10	
Endrin	0.05	
Endrin Ketone	0.05	
Heptachlor	0.05	
Heptachlor Epoxide	1.0	
Methoxychlor		
Toxaphene		

Table 4.8-2. Analytes, Analytical Methods, and Method Detection Limits for Ground-Water Samples and Surface-Water Samples, OU III Annual Monitoring Task. (Continued)

Analytical Parameter	Method Detection Limit	Analytical Method
Pesticide/PCBs (continued)	(µg/L)	EPA Method 8080
Aroclor 1016	0.5	
Aroclor 1221	0.5	
Aroclor 1232	0.5	
Aroclor 1242	0.5	
Aroclor 1248	0.5	
Aroclor 1254	1.0	
Aroclor 1260	1.0	
Herbicides		EPA Method 8150
2,4-D	1.2	
2,4-DB	0.91	
2,4,5-T	0.20	
2,4,5-TP (Silvex)	0.17	
Dalapon	5.8	
Dichloroprop	0.65	

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Section 4.0

Remedial Investigation

Figures

September 1995

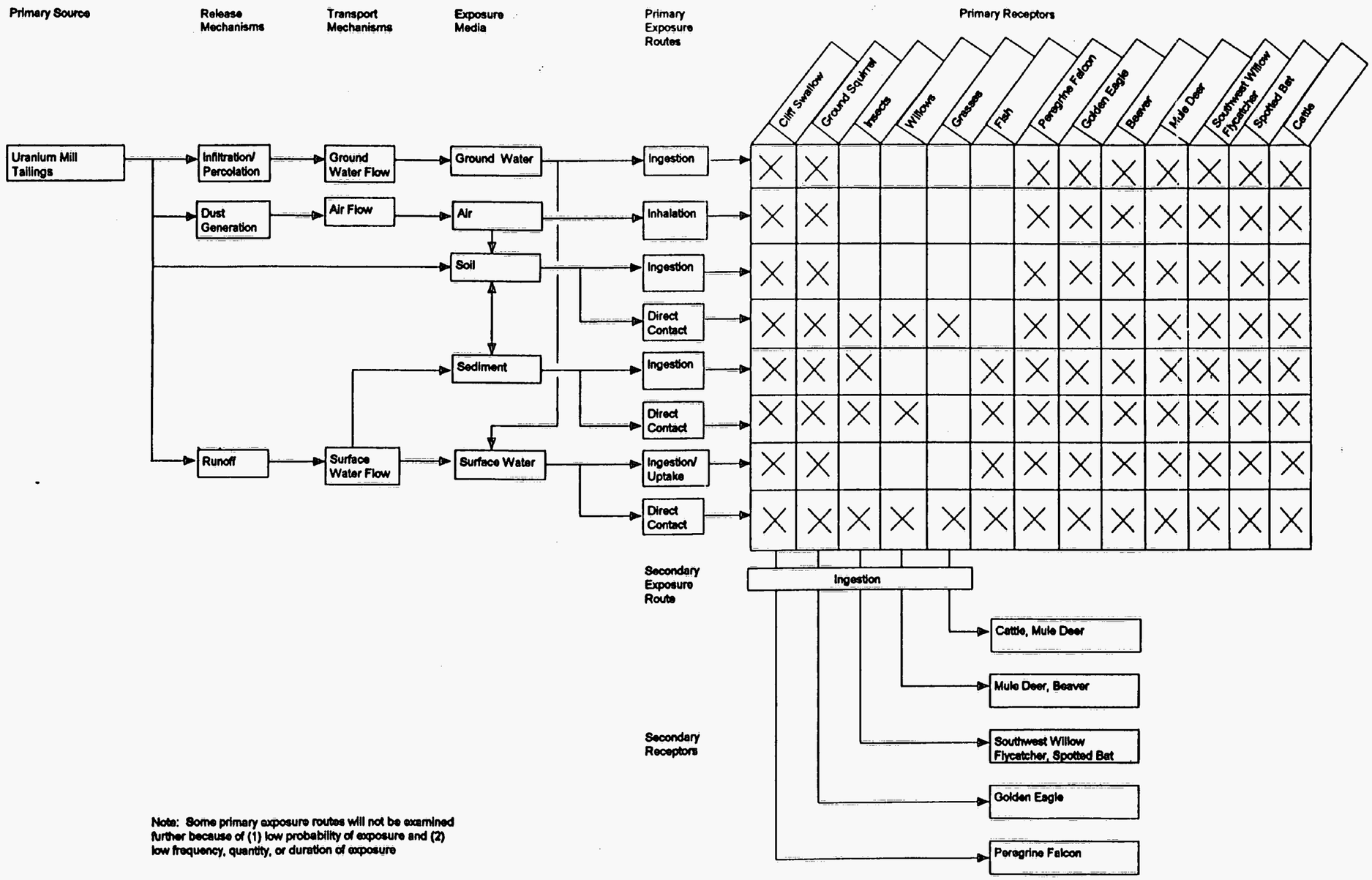


Figure 4.5-3. Preliminary Conceptual Site Model for the Ecological Risk Assessment

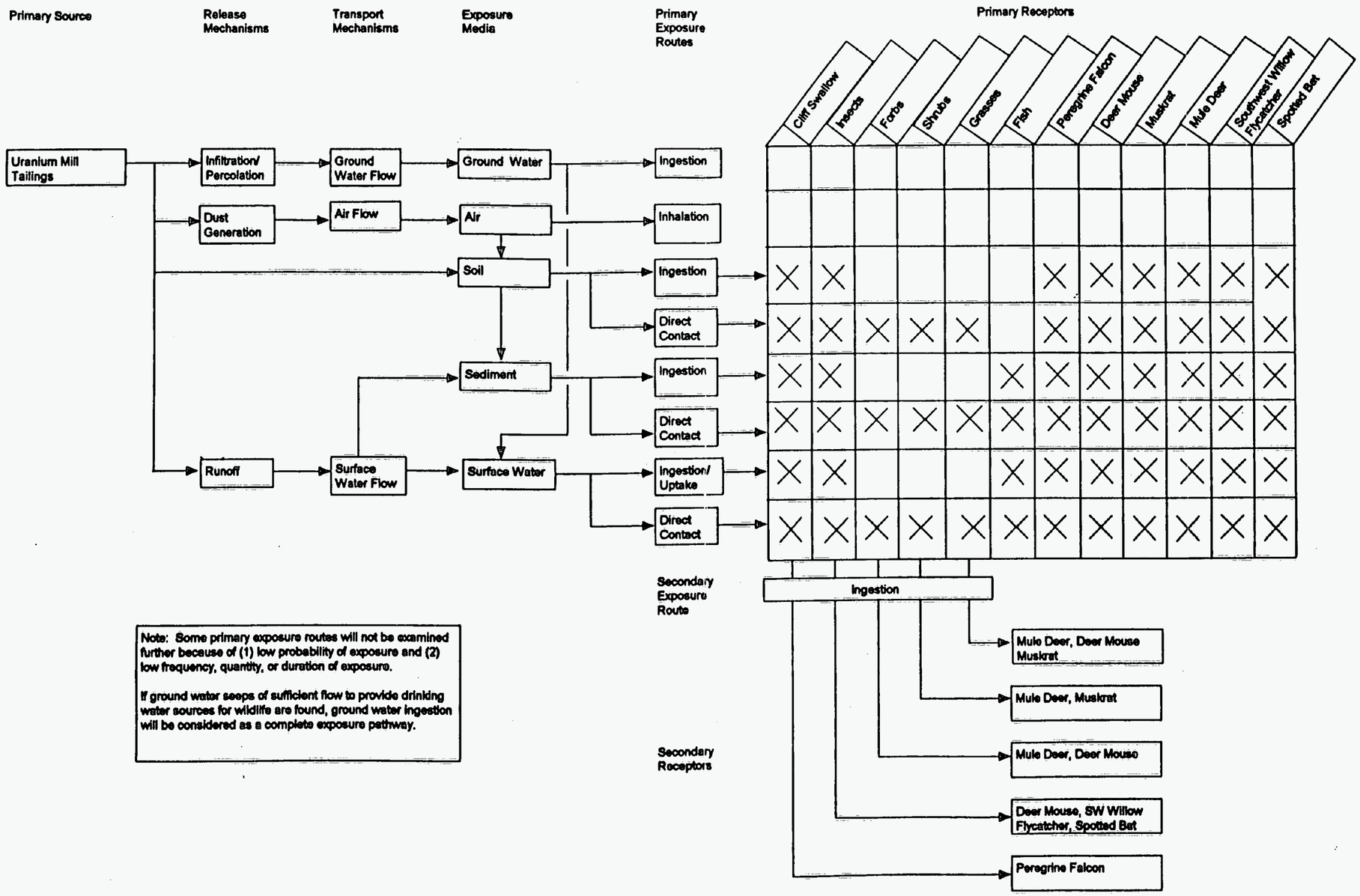
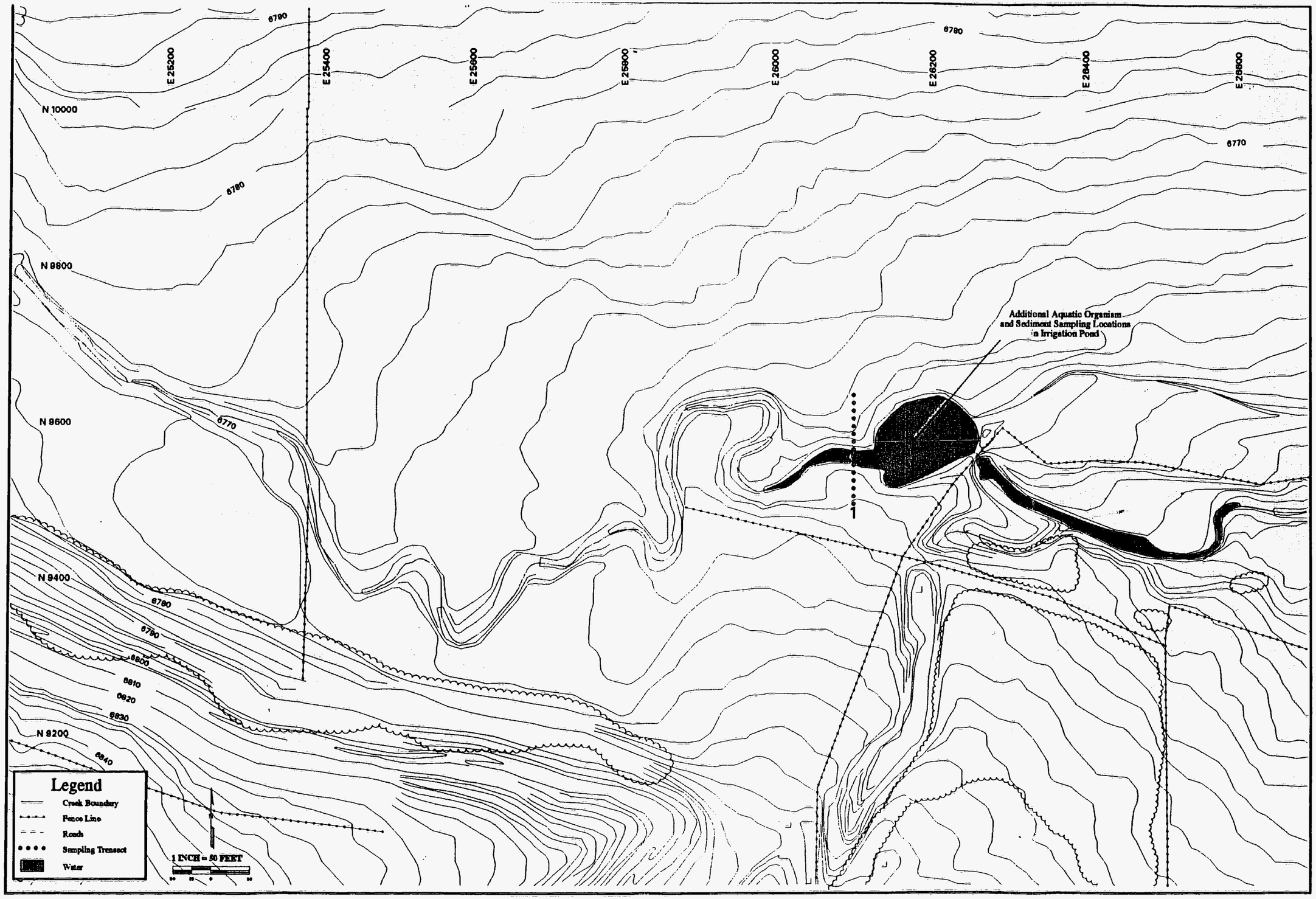
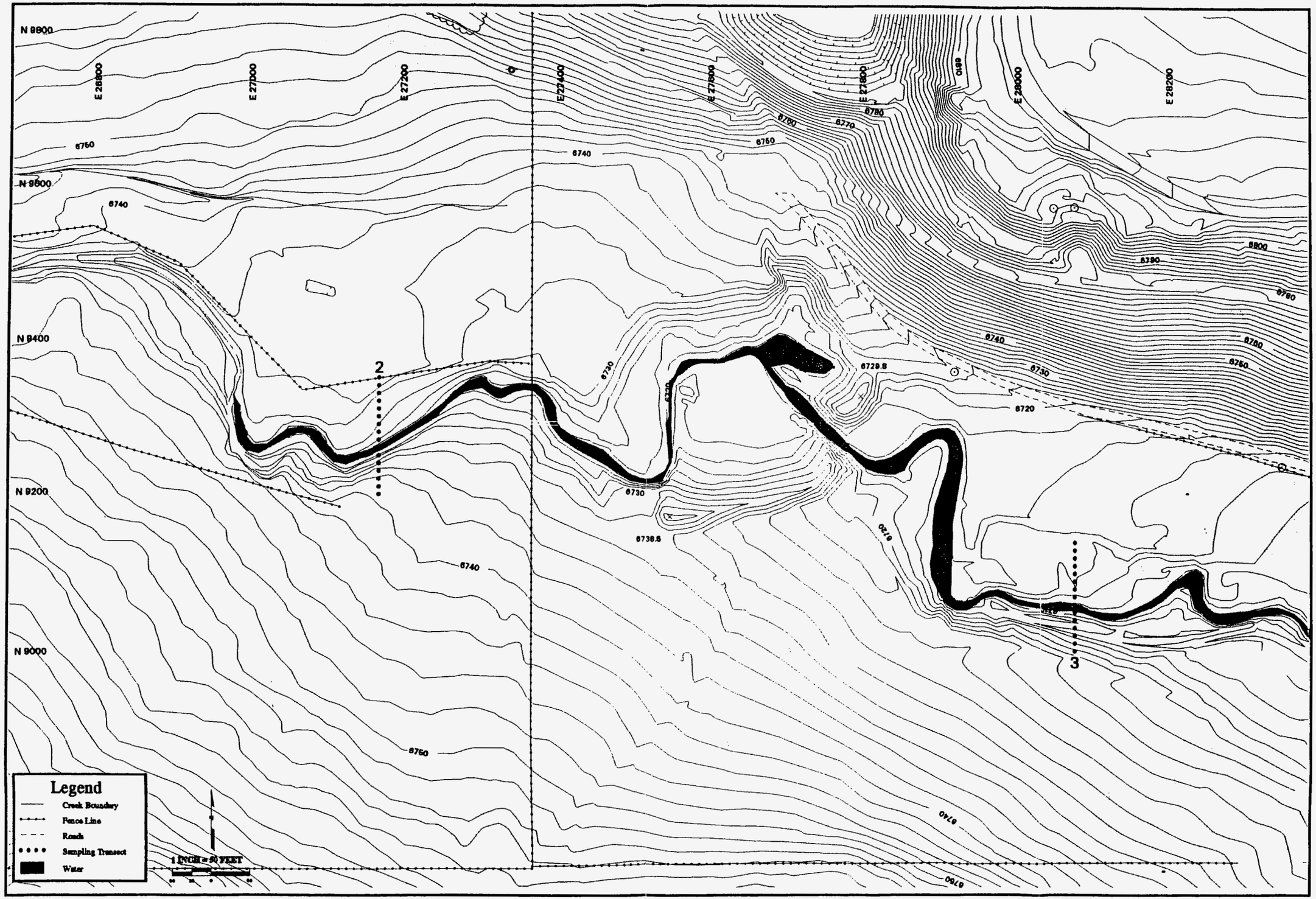


Figure 4.5-4. Conceptual Site Model for the Ecological Risk Assessment



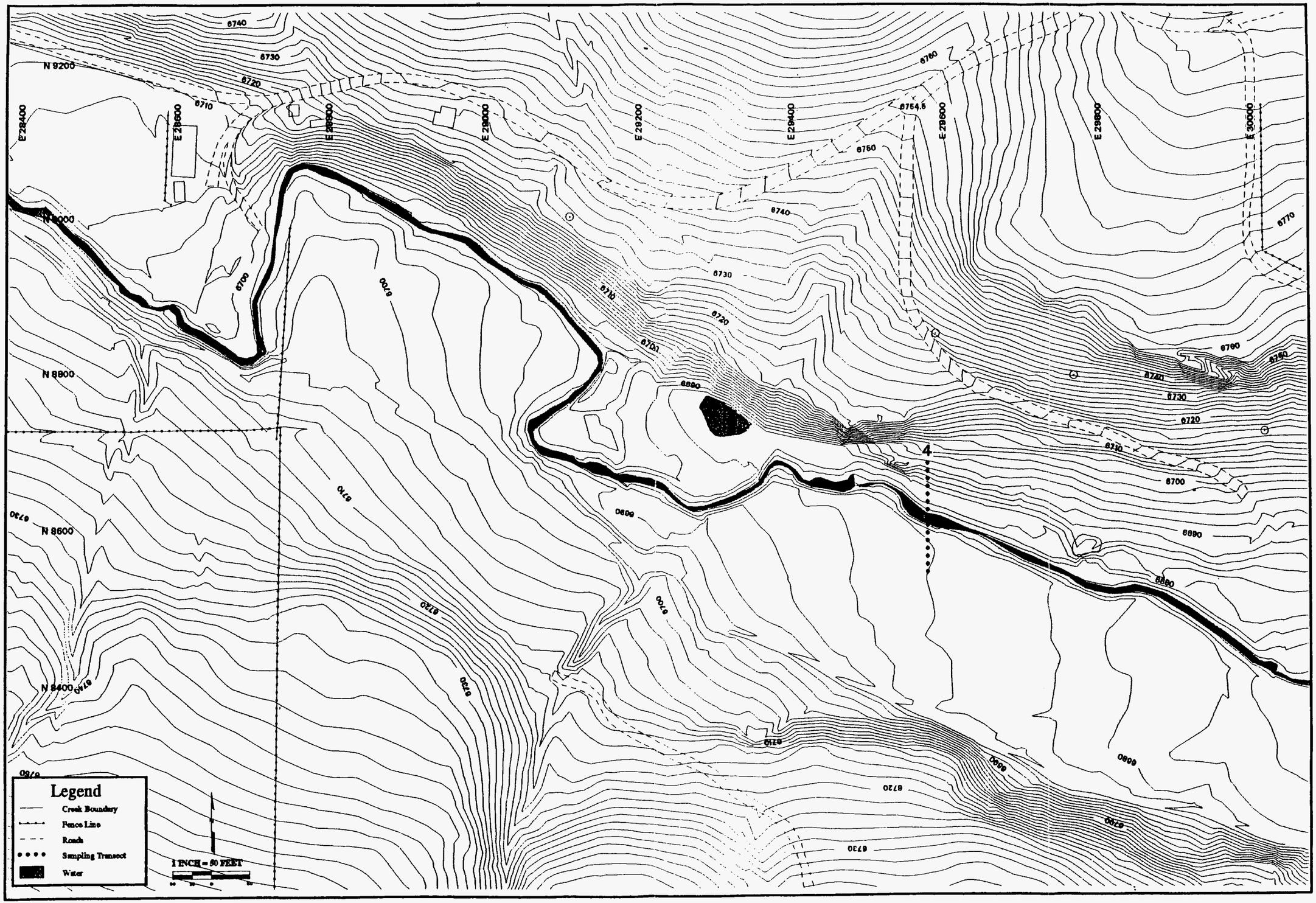
GIS Document Number: TRN-1

Figure 4.5-15. Proposed Sample Transect Locations. OU III RI/FS Study Area



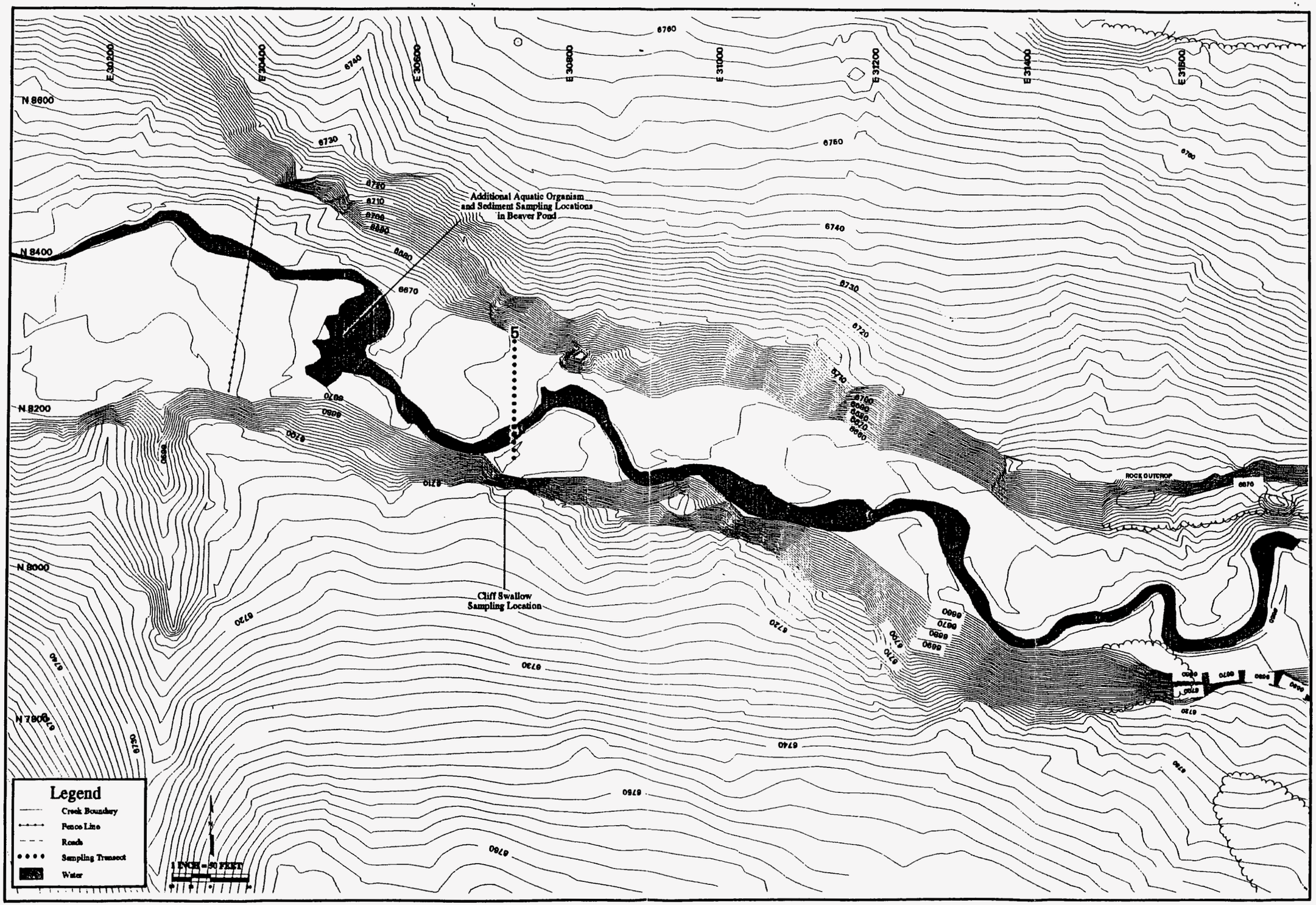
GIS Document Number: TRN-2

Figure 4.5-16. Proposed Sample Transect Locations. OU III RI/FS Study Area



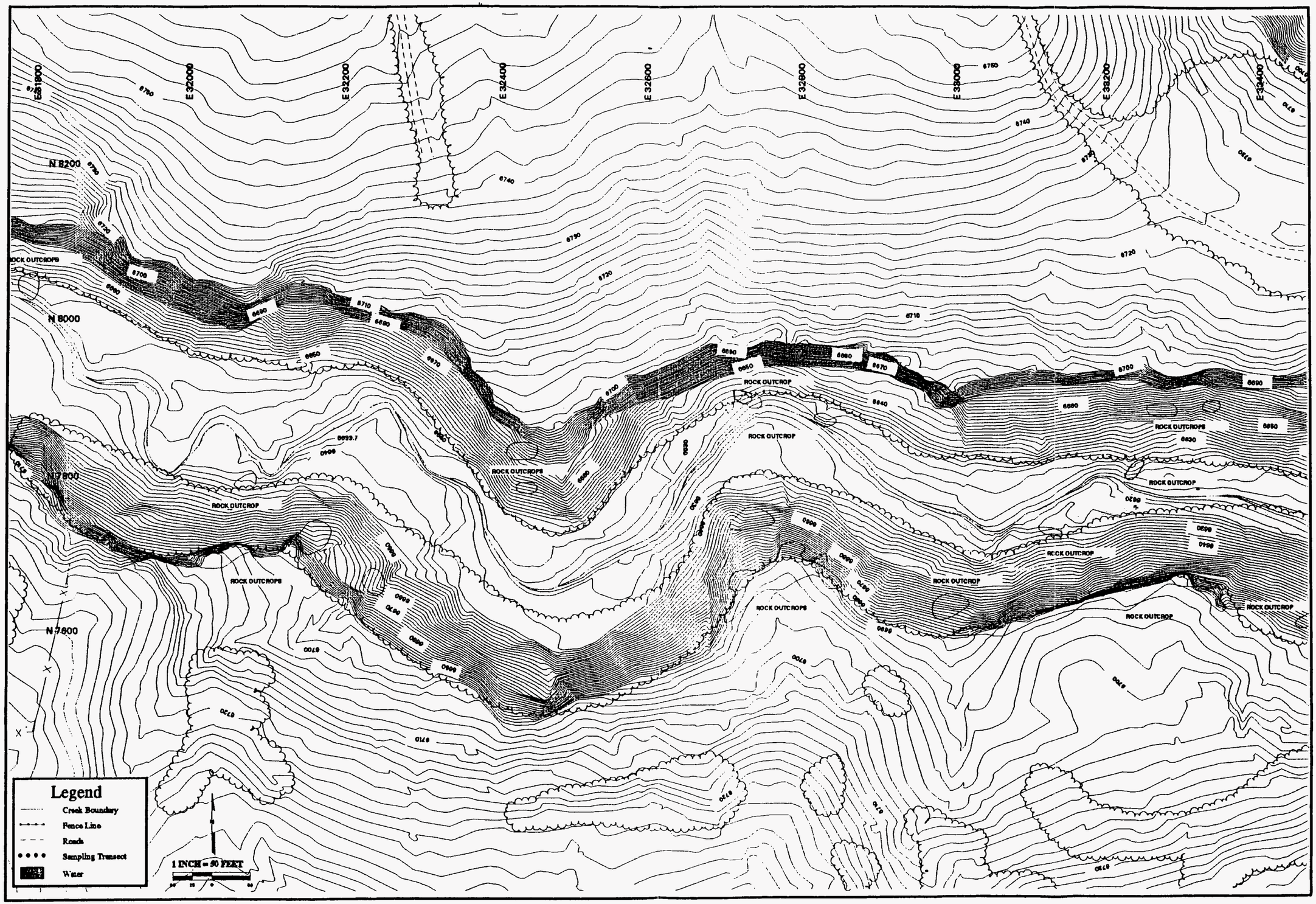
GIS Document Number: TRN-3

Figure 4.5-17 . Proposed Sample Transect Locations. OU III RI/FS Study Area



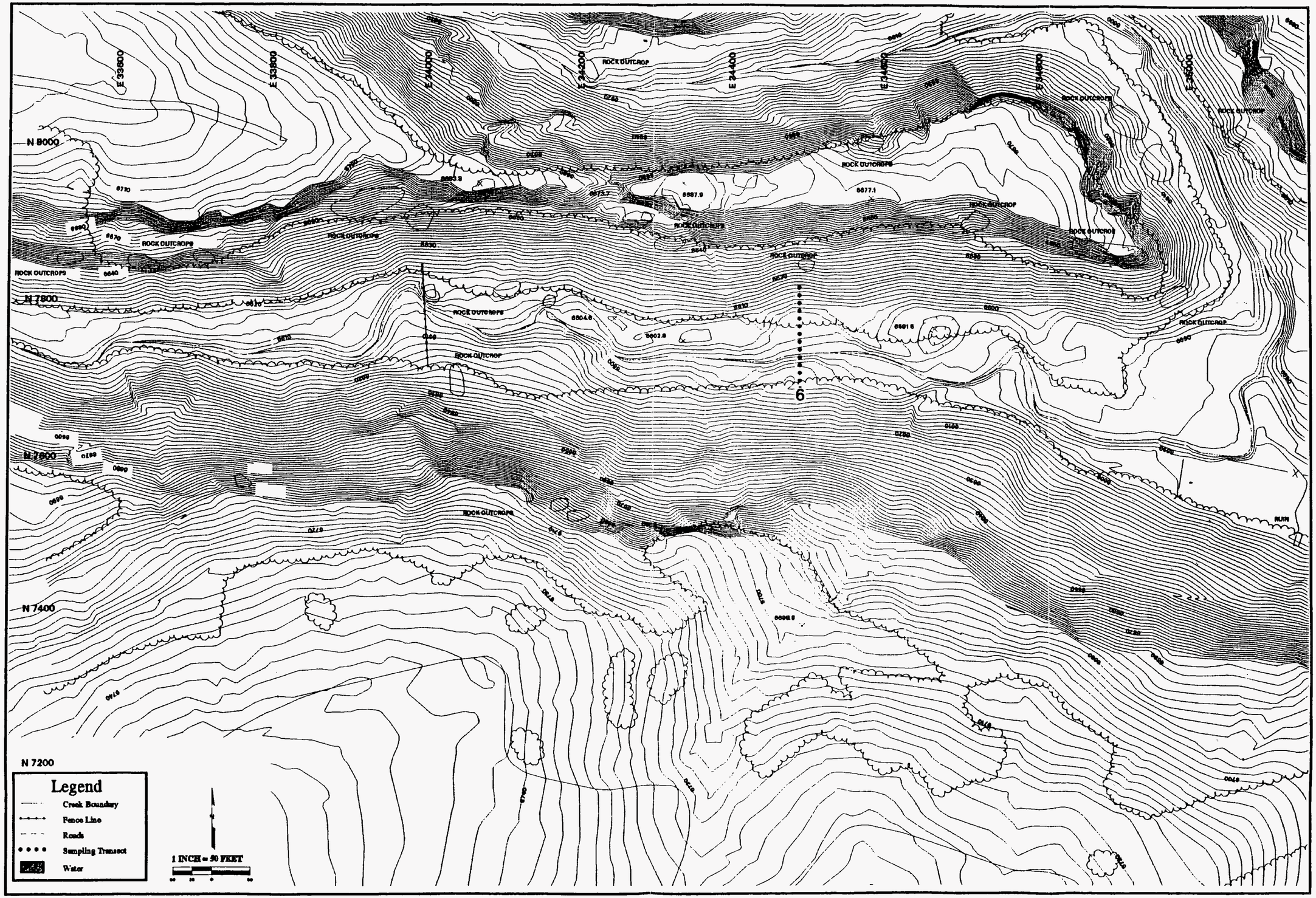
GIS Document Number: TRN-4

Figure 4.5-18 . Proposed Sample Transect Locations. OU III RI/FS Study Area



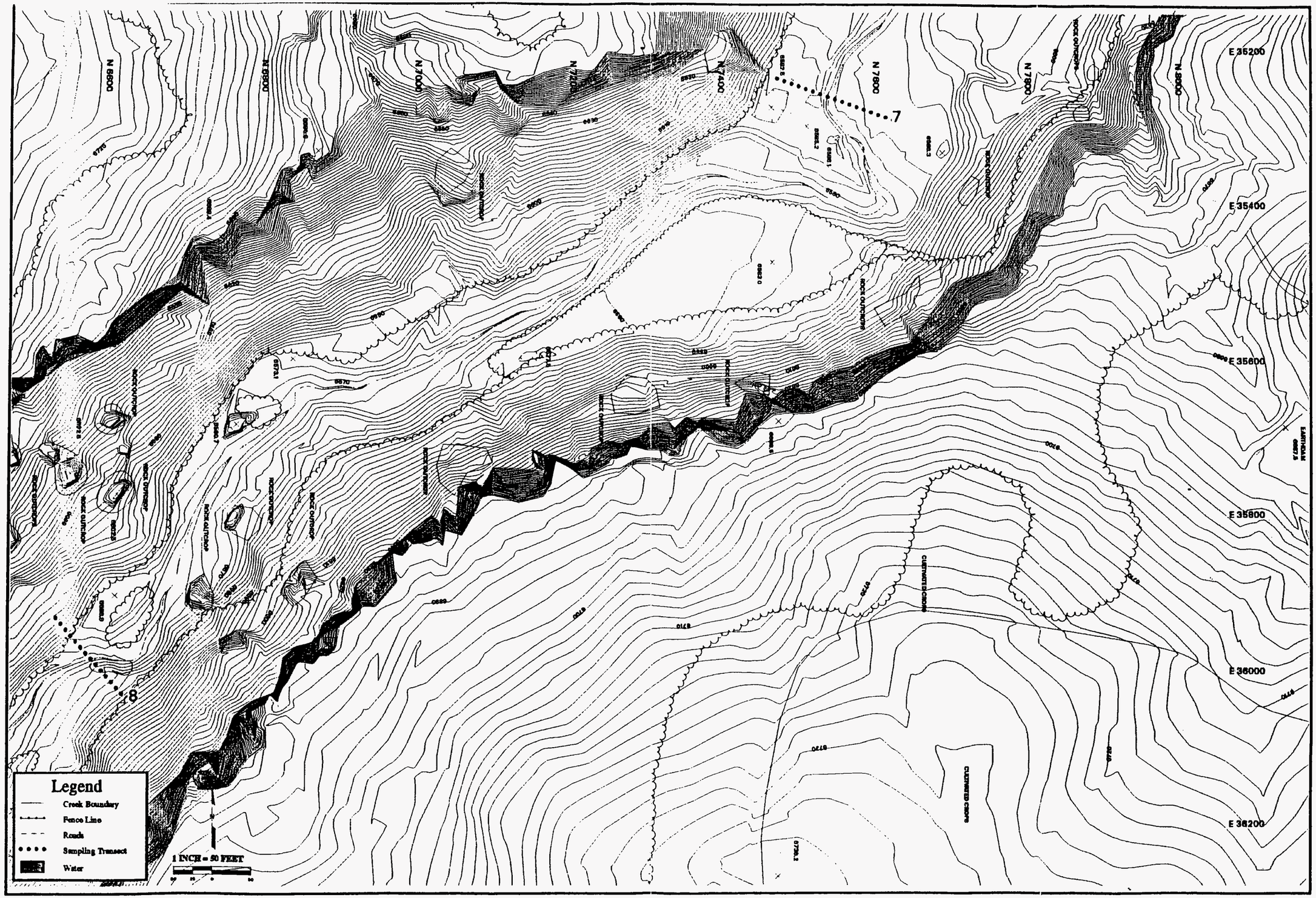
GIS Document Number: TRN-5

Figure 4.5-19. Proposed Sample Transect Locations. OU III RI/FS Study Area



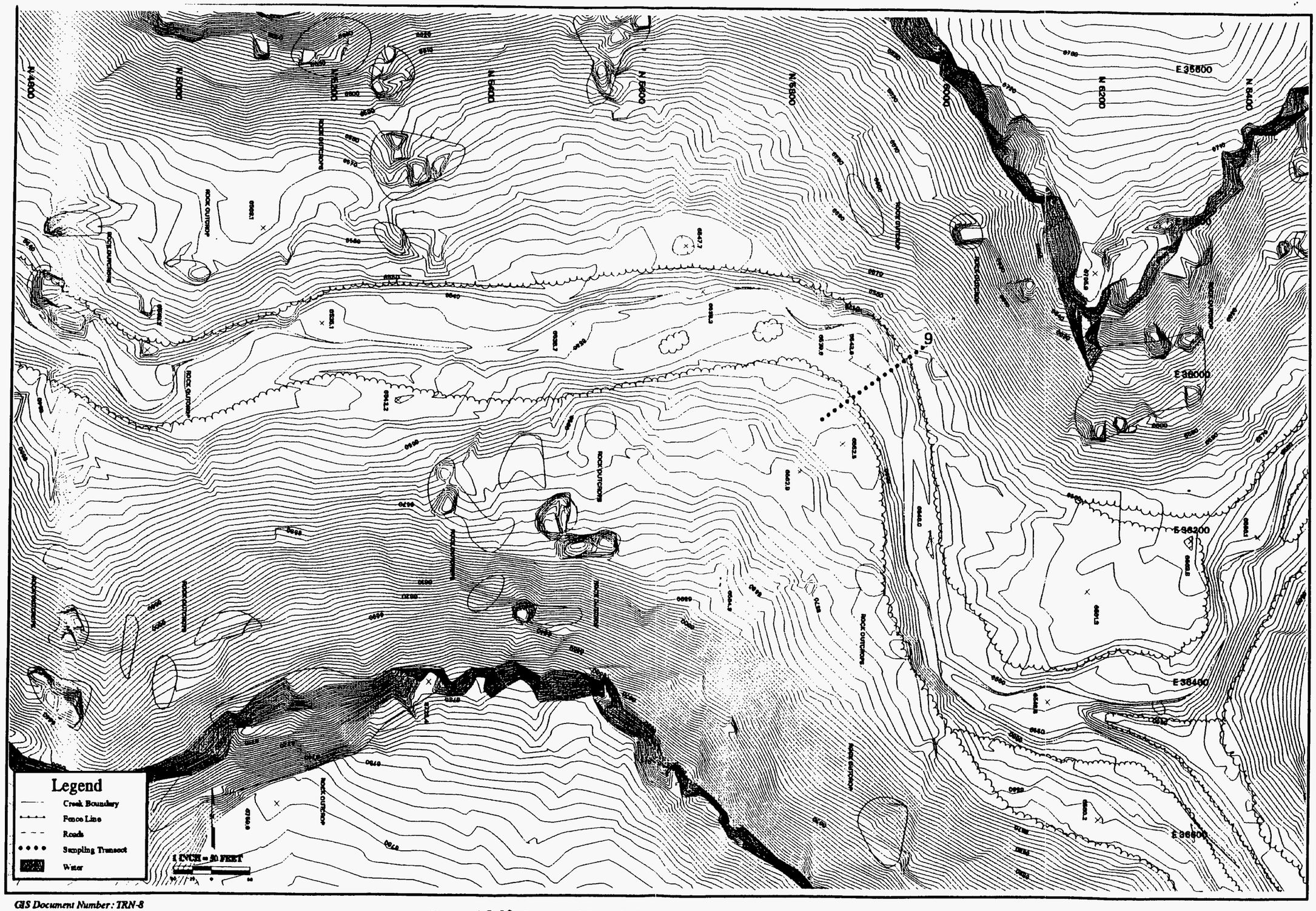
GIS Document Number: TRN-6

Figure 4.5-20. Proposed Sample Transect Locations. OU III RI/FS Study Area



GIS Document Number: TRN-7

Figure 4.5-21. Proposed Sample Transect Locations. OU III RI/FS Study Area



GIS Document Number: TRN-8

Figure 4.5-22. Proposed Sample Transect Locations. OU III RI/FS Study Area

5.0 Feasibility Study

The primary objective of the FS will be to ensure that appropriate remedial alternatives are developed and evaluated so that relevant information concerning the remedial action options can be presented to the decision makers and an appropriate remedy can be selected. As shown in Section 7.0, Schedule, the FS will be performed concurrently and in an iterative fashion with the RI and will be conducted in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988). Results of the RI will be used to refine remedial action objectives, to develop remedial action alternatives, and to support initial screening and detailed analysis of the alternatives. FS information presented in the RI/FS—EA (DOE 1990b) will be considered during implementation of the OU III FS.

The FS portion of the RI/FS will involve up to four tasks:

- Task 10: Development of Alternatives
- Task 11: Initial Screening of Alternatives
- Task 12: Detailed Analysis of Alternatives
- Task 13: Feasibility Study Report

5.1 Task 10: Development of Alternatives

Task 9 of the RI/FS involves the development of remedial alternatives. Remedial alternatives will be developed by assembling combinations of potential technologies, and the media to which they would be applied, into alternatives that address MMTS-derived contamination in surface water, ground water, sediments, and soil. It is anticipated that only a limited number of remedial technologies, and therefore alternatives, will be identified for OU III contamination, including presumptive technologies that could be expeditiously emplaced. Presumptive alternatives addressing contaminated sediment will primarily be limited to the remedies selected for OUs I and II. These remedies involve excavation of contaminated material. However, the presumptive alternatives will be expanded to include utilization of hot spot cleanup criteria and environmentally sensitive remediation. Presumptive alternatives to be considered for contamination in surface water and ground water will largely involve passive remediation and containment/treatment.

The following activities will be performed to support Task 10:

- Evaluation of ARARs
- Development of remedial action objectives and general response actions
- Identification of potentially applicable remedial technologies

- Screening of potentially applicable remedial technologies

- Development of preliminary remedial alternative

5.1.1 Evaluation of ARARs

A preliminary list of ARARs for OU III and is presented in Appendix C; these have been developed based the ARARs identified in the ROD for OUs I and II. These ARARs will be reevaluated and revised, if necessary, during completion of the RI and FS. This evaluation will include assessing the remedial Contaminants of Concern (COC), the affected media, and any physical features that may help identify location-specific ARARs. The evaluation will address each of the three types of ARARs: chemical specific, action specific, and location specific.

Chemical-specific ARARs are generally health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values for a particular site. These values establish the acceptable level or concentration of a chemical that may be present in, or discharged to, the ambient environment.

Action-specific ARARs are generally technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances. These requirements are triggered by the particular remedial activities selected to accomplish a remedy. Thus, action-specific requirements do not, in themselves, determine the remedial alternative; rather, they indicate how a selected alternative must be achieved.

Location-specific ARARs are restrictions placed on the conduct of remedial activities or the concentration of hazardous substances solely because they are occurring in a particular place.

Section 121(d)(4) of CERCLA provides EPA with the flexibility to select a remedial action that is protective of human health and the environment but that does not attain an ARAR in certain narrowly defined instances. Under both CERCLA and the NCP, compliance with ARARs can be waived under the following circumstances:

- The remedial action is an interim measure where the final remedy will attain the ARARs upon completion.

- Compliance with ARARs will result in greater risk to human health and the environment than alternative options.

- Compliance is technically impracticable.

- The remedial action selected will attain a standard of performance equivalent to that required under the otherwise applicable or relevant and appropriate requirement.

- The State has not consistently applied, or demonstrated the intent to apply consistently, the State requirement in similar circumstances at other remedial actions in the State.

5.1.2 Remedial Action Objectives and General Response Actions

Remedial action objectives (RAOs) specifying contaminants and media of concern, potential exposure pathways, and preliminary remediation goals will be developed. Preliminary RAOs and general response actions have been developed. The RAOs will be refined using results of the baseline risk assessment as appropriate. Final remediation goals will be developed on the basis of ARARs, site-specific risk-related factors developed during the baseline risk assessment, and identification of any appropriate remedial alternatives. The list of preliminary RAOs that have been developed includes:

- Prevent or reduce human exposure to carcinogens to levels of less than 1×10^{-4} excess cancer risk and exposure to noncarcinogens to levels with a hazard index less than 1.0.

- Prevent or reduce unacceptable ecological risks.

- Prevent or reduce the release of contaminants that would exceed ARARs.

As previously discussed, the number of potential general response actions will likely be limited. Those general response actions identified will define the containment, treatment, excavation, pumping, or other actions that may be taken to satisfy the RAOs for OU III. A combination or combinations of the general response actions may be pursued. The current list of presumptive response actions for OU III ground water and surface water includes:

- No Action Alternative (passive restoration with continued monitoring of ground water and surface water for a period of time established on the basis of numerical modeling results).

- Ground-water withdrawal and on-site treatment (including innovative treatment technologies, if applicable).

- Institutional controls (same as the No Action Alternative except it includes institutional control measures in addition to monitoring).

- In situ fixation (innovative technology option that involves fixation of the COCs to the aquifer media).

The current list of presumptive response actions that have been developed for sediment in the focused study area includes:

- No Action Alternative (only includes monitoring).

- Institutional controls (the same as the No Action Alternative except it includes institutional control measures).

- Excavation of contaminated sediments.

As specified in the NCP, the No Action Alternative will be carried through the final alternatives analysis to serve as a baseline for evaluating other alternatives.

5.1.3 Potentially Applicable Remedial Technologies

A list of potentially applicable remedial technologies will be developed on the basis of RI results, preliminary RAOs, and the preliminary general response actions. Innovative or alternative treatment technologies will be included whenever possible and evaluated equally with demonstrated technologies. An innovative technology will be considered if the technology offers (1) the potential for comparable or superior performance or implementability, (2) fewer or less adverse impacts than other available approaches, or (3) lower costs for levels of performance similar to that of demonstrated treatment technologies.

Initially, each technology will be evaluated for appropriateness under site-specific conditions. Technologies found appropriate under site-specific conditions will be used to assemble remedial action alternatives to address MMTS concerns, if any. Remedial technologies to be considered include (1) technologies that use treatment technologies to reduce the toxicity, mobility, or volume of contaminants, (2) technologies designed to prevent or control exposure to contaminants through engineering controls and institutional controls, (3) technologies that attain site-specific remediation levels within different restoration time periods, and (4) No Action Alternatives, given millsite remediation is being conducted under OU I.

5.1.4 Screening of Potentially Applicable Remedial Technologies

After potential remedial technologies are identified, each technology will initially be screened to determine how effective it is with respect to the protection of human health and the environment. This initial screening will focus on the degree to which the technology (1) reduces toxicity, mobility, or volume through treatment, (2) minimizes residual risks and affords long-term protection, (3) complies with ARARs, and (4) minimizes short-term impacts. The initial screening step also will include assessment of how quickly each technology will achieve protection. Technologies that do not provide adequate protection of human health and the environment will be eliminated from further consideration.

5.1.5 Development of Preliminary Remedial Alternatives

The technology processes judged to be technically implementable will be evaluated further to select process options that represent each technology type. The relevant process options will be assembled into potential remedial alternatives.

Treatment is not considered a potential alternative for contaminated sediment in the focused study area. If remediation of sediment is necessary, sediment will be remediated in a manner consistent with the preferred alternative selected for OUs I and II. The preferred alternative selected for OUs I and II involves removal and placement of contaminated material in the permanent on-site repository. Treatment will be considered for remediation of contaminated media if RI results indicate that, after remediation under OUs I and II is complete, ARARs are exceeded or contaminated media pose an unacceptable risk to human health or the environment. Alternatives for surface water and ground water will be developed that consider:

- Treatment options that would reduce toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as their principal element.
- A treatment option that removes or destroys hazardous substances, pollutants, or contaminants to the maximum extent feasible, eliminating or minimizing the need for long-term management (including monitoring) at the site.
- Treatment alternatives that, at a minimum, treat the principal threats posed by the site but vary in the degree of treatment employed and the quantities and characteristics of the treatment residuals and untreated waste that must be managed.
- Limited number of remedial alternatives for ground water that attain site-specific remediation levels within different restoration time periods using one or more different technologies.
- One or more innovative treatment technologies if these technologies offer the potential for comparable or superior performance or implementability, fewer or less adverse impacts than other available approaches, or lower costs for levels of performance similar to that of demonstrated treatment technologies.
- One or more containment options that involve little or no treatment but provide protection of human health and the environment, primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants.
- The No Action Alternative.

In addition, the NCP states that the alternatives should, as appropriate, consider and integrate waste minimization, destruction, and recycling.

The intended purpose of this initial examination is not only to ensure that all regulatory requirements have been met, but also to ensure that potential alternatives are sufficiently diverse to allow for a range of potential benefits and associated costs to be examined during the FS.

5.2 Task 11: Initial Screening of Alternatives

The assembled alternatives developed during Task 9 will be refined and screened in coordination with the EPA and State to reduce the number of alternatives to be evaluated in

detail during Task 10. The criteria to be used in screening are (1) effectiveness in contributing to the protection of human health and the environment, (2) implementability, and (3) cost of alternative implementation. Because the FS will be conducted using a focused approach, this task will be greatly simplified and may result in no change to the number of alternatives identified.

5.2.1 Effectiveness Evaluation

Each alternative will be evaluated with respect to the degree to which the alternative reduces toxicity, mobility, or volume through treatment, minimizes residual risks and affords long-term protection, complies with ARARs, minimizes short-term impacts, and achieves protection of human health and the environment within current and future likely land use scenarios and within an acceptable period of time. Land use scenarios will be evaluated in the BRA portion of the RI. Applicable land uses will then be used in this portion of the FS. The current land use in Montezuma Canyon is residential/agricultural in the upper portion and recreational/ agricultural in the lower portion. It is likely that these land uses will remain in the future.

The potential effectiveness of each alternative in protecting human health and the environment will be qualitatively evaluated by comparing the reductions in potential exposure or risk associated with the alternative against the potential exposures or risks associated with the No Action Alternative as described in the baseline risk assessment. The baseline risk assessment routinely constitutes the basis for analysis of the No Action Alternative against which other alternatives are compared.

Alternatives that provide similar protection of human health and the environment will be identified. Alternatives that may introduce significant adverse impacts or that do not adequately protect human health or the environment will be eliminated. However, only alternatives with a clear potential for causing adverse effects will be eliminated on the basis of the effectiveness criteria.

5.2.2 Implementability Evaluation

Implementability is a measure of both the technical and the administrative feasibility of constructing, operating, and maintaining a remedial action alternative. Each alternative will be screened to eliminate alternatives that cannot be implemented using acceptable engineering practices or are not compatible with site conditions. Each alternative will be evaluated to determine if the alternative is feasible with respect to location and condition of the site, is applicable to the problem, and is a reliable means of addressing the problem within a reasonable period of time.

Examples of implementability considerations are whether the equipment required for a technology can physically be brought into the canyon or whether a technology can be implemented in time to deposit any excavated soils or sediments in the on-site repository. A preference will be given to technologies that can be implemented in time to deposit material in the on-site repository.

5.2.3 Cost Screening

Preliminary estimates of capital costs and long-term operation and maintenance (O&M) costs will be developed for each remedial alternative that passes the effectiveness and implementability screening. These cost estimates will be made primarily on the basis of published cost data prepared by EPA and its contractors, construction industry standards, and DOE's experience with similar projects (including remediation under OUs I and II). Design and unit cost assumptions that significantly affect the total cost estimate of remedial alternatives will be identified. A present-worth analysis will be prepared to allow remedial alternatives with different levels of capital and O&M costs to be compared on an equal basis.

Remedial alternatives will be compared on the basis of capital costs, O&M costs, and present worth. Comparison results will be used to identify the most cost-effective remedial alternative, alternatives offering similar benefits with similar estimated costs, and alternatives displaying the highest estimated costs for similar levels of benefit. Alternatives with the highest estimated costs for similar levels of benefit will be eliminated from further consideration.

5.3 Task 12: Detailed Analysis of Alternatives

Detailed analysis of each remaining remedial action alternative will be performed following the initial screening of alternatives. Three steps will be used to conduct the detailed analysis of alternatives:

- Step 1–Further definition of each alternative, if appropriate, with respect to the volumes or areas of contaminated media to be addressed, the technologies to be used, and any performance requirements associated with those technologies.

- Step 2–An assessment and a summary of each alternative on the basis of relative performance with respect to the nine evaluation criteria specified in the NCP (see Section 5.3.2, Evaluation Criteria).

- Step 3–A comparative analysis among the alternatives to assess the relative performance of each with respect to each evaluation criterion.

The end result of the detailed analysis of alternatives will be an assessment of the relative merits and costs associated with each alternative. This information will form the basis for a preferred alternative, which will be recommended in the final FS report.

5.3.1 Alternatives Definition

Each alternative will be reviewed to assess whether additional definition is required to apply the evaluation criteria consistently and to develop order-of-magnitude cost estimates (i.e., having a desired accuracy of +50 percent to -30 percent). This process will include identifying institutional controls that complement the individual remedial alternatives.

5.3.2 Evaluation Criteria

The detailed analysis of alternatives provides the means by which facts are assembled and evaluated to develop the rationale for remedy selection. The evaluation process to be used for OU III was developed on the basis of statutory requirements of CERCLA Section 121 and the NCP. The nine evaluation criteria detailed below encompass statutory requirements and technical, cost, and institutional considerations.

In consideration of DOE's policy to comply with the National Environmental Policies Act (NEPA), the FS will incorporate, to the extent practicable, NEPA values into the nine CERCLA evaluation criteria (DOE 1994c). NEPA values include analysis of cumulative, off-site, ecological, and socioeconomic impacts.

5.3.2.1 Threshold Criteria

The NCP had established two threshold criteria that each alternative must meet at a minimum (1) overall protection of human health and the environment and (2) compliance with ARARs.

Overall Protection of Human Health and the Environment: Alternatives will be evaluated to assess whether they can adequately protect human health and the environment, in both the short term and long term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants associated with the MMTS. Alternatives will be evaluated regarding their ability to eliminate, reduce, or control exposures to levels established during development of remediation goals consistent with 40 CFR Part 300.430(e)(2)(I). Overall protection of human health and the environment draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

The baseline risk assessment will identify exposure pathways and will discuss fate and transport of MMTS-derived contaminants. The evaluation of overall protectiveness of each alternative will focus on whether the alternative achieves adequate protection and will describe how the alternative serves to eliminate, reduce, or control risks posed through each pathway.

Compliance with ARARs: The alternatives will be evaluated to determine whether they attain ARARs under Federal and State environmental laws or provide the grounds for invoking one of the waivers under paragraph (f)(1)(ii)(C) of 40 CFR Part 300.430. Activities performed in support of the detailed analysis of alternatives will include summarizing which requirements are applicable or relevant and appropriate and describing how the alternative meets these requirements.

5.3.2.2 Balancing Criteria

The five criteria upon which the alternatives are compared and contrasted are (1) long-term effectiveness and permanence, (2) reduction of toxicity, volume, or mobility through treatment, (3) short-term effectiveness, (4) implementability, and (5) cost.

Long-Term Effectiveness and Permanence: Alternatives will be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that will be considered, as appropriate, include:

- The magnitude of residuals remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals will be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

- The adequacy and reliability of controls, if any, that are used to manage treatment residuals and untreated wastes that remain at the site. This factor includes assessment of the potential need to replace components of the alternative, such as a pump and treat system, and the potential exposure pathways and risks posed if the remedial action needs replacement.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The degree to which alternatives employ recycling or treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element will be assessed. This assessment will include how treatment is used to address the principal threats posed by the site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.

This assessment will focus on the following specific factors for a particular remedial alternative:

- The treatment or recycling processes that the alternative will employ and the media the treatment process will treat.

- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled.

- The expected degree of reduction in toxicity, mobility, or volume of the waste due to treatment or recycling, measured as a percentage or order of magnitude.

- The degree to which treatment is irreversible.

- The degree to which treatment reduces the inherent hazards posed by principal threats at the site.

Short-Term Effectiveness: Short-term effectiveness addresses the effects of the remedial alternative during the construction and implementation phases. Alternatives will be evaluated with respect to their effects on human health and the environment during implementation of the remedial action. The short-term impact of alternatives will be assessed by considering the following:

- Short-term risks that might be posed to the community during implementation of the alternative.

- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures.

- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation.

- Time until protection is achieved.

Implementability: Implementability is a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial alternative given site conditions. The ease or difficulty of implementing the alternative will be assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions).

- Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies.

Cost: The types of costs that will be assessed include the following:

- Capital costs, including both direct and indirect costs

- Annual O&M costs

- Net present value of capital and O&M costs (present worth)

To the extent possible, order of magnitude cost estimates (+50 to -30 percent) will be developed.

5.3.2.3 Modifying Criteria

The final two criteria, State and community acceptance, will not be addressed until a final decision is being made. State acceptance will be included in the Proposed Plan presented for public comment. Community acceptance will be included in the ROD.

State Acceptance: The State will review the draft FS Report and will have an opportunity to provide comments. The State concerns that will be assessed include:

- The State's position and key concerns related to the preferred alternative and other alternatives.
- State comments on ARARs or the proposed use of waivers.

Technical and administrative concerns raised by the State in its comments regarding each alternative will be evaluated and addressed.

Community Acceptance: The preferred alternative(s) for the site will be presented to the public in the Proposed Plan, which will provide a brief summary of all of the alternatives studied in the Detailed Alternatives Analysis of the FS. In accordance with the NCP, the public will have an opportunity to review and comment on the selected remedial alternatives presented in the Proposed Plan. The public's comments will be addressed in the responsiveness summary and ROD.

5.3.3 Comparative Analysis of Alternatives

When the alternatives have been described and individually assessed against the criteria, a comparative analysis will be conducted to evaluate the performance of each alternative relative to each specific evaluation criterion. This analysis is in contrast to the preceding analysis in which each alternative was analyzed independently without consideration of other alternatives. The purpose of this comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others.

The comparative analysis will include a narrative discussion describing the strengths and weaknesses of the alternatives relative to one another with respect to each criterion and how reasonable variations of key uncertainties could change the expectations of their relative performance. A brief summary of those comparisons also will be prepared.

5.4 Task 13: Feasibility Study Report

If site risks warrant performing an FS, all aspects of the FS will be documented in the FS Report. The format of the FS Report will be consistent with EPA guidelines specified in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), and will be flexible to reflect the level of detail necessary to reach a decision.

A removal action may be used to remediate sediments and/or soils in the focused study area. In anticipation of this possibility and because of the limited time available to prepare documentation for a removal action, the detailed analysis of alternatives for sediments and soils will include information required for completion of an EE/CA. If a remedial action(s) is required, the FS, and especially the detailed analysis of alternatives, will be the basis of the remedial design.

The FS Report will accomplish the following objectives:

- Ensure that human health and the environment and all major issues are adequately addressed.
- Ensure adequate documentation of the decision-making process.
- Provide recommended remedies for MMTS-derived contaminated media and sediment in the focused study area.

A proposed outline for the FS Report is presented in Table 5.4-1.

Table 5.4-1. Proposed Feasibility Study Report Outline

Table of Contents

Executive Summary

1.0 Introduction
- 1.1 Purpose and Organization of the Report
- 1.2 Background Information
  - 1.2.1 Site Description
  - 1.2.2 Site History
  - 1.2.3 Nature and Extent of Contamination
  - 1.2.4 Contaminant Fate and Transport
  - 1.2.5 Summary of Baseline Risk Assessment
  - 1.2.6 Applicable or Relevant and Appropriate Requirements Summary

2.0 Identification and Screening of Technologies
- 2.1 Introduction
- 2.2 Remedial Action Objectives
- 2.3 Preliminary Remediation Goals
- 2.4 General Response Actions
- 2.5 Identification and Screening of Technology Types and Process Options
  - 2.5.1 Identification of Technologies Associated with the General Response Actions
  - 2.5.2 Screening Criteria
  - 2.5.3 Screening of Technologies
  - 2.5.4 Selection of Representative Technologies

3.0 Development of Alternatives

4.0 Initial Screening of Remedial Action Alternatives
- 4.1 Introduction
- 4.2 Screening Criteria
- 4.3 Alternative Analysis
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5.0 Detailed Analysis of Alternatives
- 5.1 Introduction
- 5.2 Alternatives Definition
- 5.3 Comparison Among Alternatives
  - 5.3.1 Overall Protection of Human Health and the Environment
  - 5.3.2 Compliance with Applicable or Relevant and Appropriate Requirements
  - 5.3.3 Short-Term Effectiveness
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  - 5.3.5 Reduction of Toxicity, Mobility, or Volume Through Treatment
  - 5.3.6 Implementability
  - 5.3.7 Cost
  - 5.3.8 State Acceptance
  - 5.3.9 Community Acceptance
  - 5.3.10 Summary of Comparisons Among Alternatives

6.0 Recommended Remedy

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6.0 Proposed Plan/Record of Decision

6.1 Proposed Plan

The Proposed Plan will supplement the RI/FS with risk management judgments and will provide the public with the rationale for selecting the preferred alternative for remedial action (which may include the No Action Alternative). The results of the comparative analysis of alternatives performed during Task 12 of the RI/FS combined with risk management judgments made by members of the triparty agreement become the rationale for selecting a preferred alternative and preparing a Proposed Plan. The Proposed Plan will be prepared in accordance with *Guidance on Preparing Superfund Decision Documents* (EPA 1989b).

As explained in Section 1.2, Technical Approach, one Proposed Plan is planned for OU III. However, circumstances may require that two Proposed Plans be prepared, one for sediments and/or soils and one for surface water and ground water. Alternatively, a combined Proposed Plan may address the sufficiency of any removal action completed for the soils and/or sediments. A removal action is planned for any required cleanup of sediments and soils in the focused study area, if deemed appropriate by EPA and the State.

The objectives of the Proposed Plan are:

- Briefly describe the remedial alternatives analyzed.
- Identify and discuss the rationale that supports the preferred alternative.
- Summarize formal comments received from the reviewing agencies.
- Summarize the explanation of any proposed waiver of an ARAR.

Following preparation of the Proposed Plan, the following community involvement activities will be conducted:

- Publish a notice of availability of the Proposed Plan, including a brief analysis of the Proposed Plan, in the Blanding and Monticello, Utah, newspapers.
- Make the Proposed Plan and supporting analysis information available in the administrative record.
- Provide an opportunity for submission of comments on the Proposed Plan.
- Hold a public meeting in Monticello regarding the Proposed Plan.

- Prepare a transcript of the public meeting and make the transcript available to the public.

- Prepare a Responsiveness Summary documenting new relevant information submitted during the public comment period and the response to each issue.

6.2 Record of Decision

The last step of the remedy selection process is to make the final remedy selection decision and document that decision in a ROD. In preparation of the OU III ROD, the preferred alternative will be reassessed on the basis of new information or points of view expressed by the reviewing agencies and community during the public comment period. Final remedy selection will be based on the mutual agreement of DOE, EPA, and the State. However, selection of the remedy ultimately rests with EPA, especially if the parties do not agree. The ROD will be prepared in accordance with *Guidance on Preparing Superfund Decision Documents* (EPA 1989b).

As explained in Section 1.2, Technical Approach, one ROD is planned for OU III. However, circumstances may require that two RODs be prepared, one for sediments and/or soils and one for surface water and ground water. Alternatively, a combined ROD may address the sufficiency of any removal action completed for the soils and sediments. A removal action is planned for any required cleanup of sediments and/or soils in the focused study area, if deemed appropriate by EPA and the State.

The ROD will describe the following statutory requirements as they relate to the scope and objectives of the action:

- How the selected remedy is protective of human health and the environment.

- How the remedy will attain the Federal and State requirements that are applicable or relevant and appropriate to the site.

- Any ARARs that the remedy will not meet, the waiver involved, and the justification for invoking the waiver.

- How the remedy is cost-effective.

- If applicable, how the remedy uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

- If the remedy was selected for its ability to permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances or why such a remedy was not selected.

In addition, the ROD will present:

- Description of alternatives.
- Comparative analysis of alternatives using the nine CERCLA criteria.
- The remedial goals that the remedy is expected to achieve.
- Summary of site risks.
- The significant changes and the response to comments on the Proposed Plan, and highlights of community participation.
- Description of any contingencies placed on the ROD.
- Summary of site characteristics.
- Whether hazardous substances, pollutants, or contaminants will remain on the site and a review of the remedial action will be required at least every five years.
- Site name, location, description, and history.
- Commitment for further analysis and selection of long-term response measures within an appropriate time frame, when appropriate.

Upon signature of the ROD by DOE, EPA, and the State, the following community involvement activities will be conducted:

- Publish notice of availability of the ROD in the Blanding and Monticello, Utah, newspapers.
- Make the ROD available for public inspection and copying before the commencement of any remedial actions.

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7.0 Project Schedule

The schedule for OU III is presented in Figure 7.0-1. The schedule contains target completion dates as well as the enforceable milestone dates established in the *Monticello Site Management Plan* (DOE 1995b) for submittal of primary documents to EPA and the State.

The DOE is utilizing the EPA's SACM approach to expedite completion of the RI/FS. As a result, target completion dates are projected to occur well in advance of enforceable milestone dates. The SACM approach is being used to streamline the ecological and human health risk assessments and refine the scope of work for the ground-water modeling effort. The streamlined approach for the ecological risk assessment and human health risk assessment and the refined scope for the ground-water modeling effort are presented in Sections 4.5, 4.6, and 4.7 of this Work Plan, respectively.

The OU III schedule was developed on the basis of the following assumptions:

- Regulatory reviews, comments, and approvals are received within the allotted time frames (per the FFA).
- Agreements for access to on-site and reference area monitoring/sampling sites are received within the allotted time frames.
- An open communication network is maintained among DOE-GJPO, EPA, and the State to allow timely resolution of problems and conflicts encountered during implementation of the RI/FS.
- Input is received from EPA and the State regarding performance criteria and future land use before initiation of flow and transport modeling.
- A single Proposed Plan and ROD will be prepared for OU III; separate Proposed Plans and RODs for sediment/soil and surface water/ground water will not be required.

Key elements of the proposed schedule are

- All fieldwork described in this Work Plan will be initiated in Spring 1995 and completed in Fall 1995.
- Ground-water flow and transport modeling will be completed in March 1996.
- A draft RI report will be submitted for regulatory review in May 1996. A draft FS report will be submitted for regulatory review in October 1996. Draft Final versions of the RI and FS reports will be submitted for regulatory review in September 1996 and January 1997, respectively. The stipulated penalty milestone for the draft final documents is June 19, 1997.

- A draft Proposed Plan and draft ROD will be submitted for regulatory review in June 1997 and January 1998, respectively. Draft Final versions of the Proposed Plan and ROD will be submitted for regulatory review in July 1997 and March 1998, respectively. The stipulated penalty milestones for the draft final Proposed Plan and ROD are May 22, 1998 and January 11, 1999, respectively.

- The RI/FS report and Proposed Plan will be submitted for public review and comment in August 1997.

- Remedial design/action specified in the ROD will be initiated in April 1998.

Additionally, the DOE intends to utilize early actions, with EPA and State concurrence, to further expedite completion of the OU III project. The use of early actions is consistent with the EPA's SACM approach. Early actions and supporting documentation are not shown in the OU III schedule, because it is not yet known whether such actions are warranted. However, the DOE has determined, based on expected land use and results of preliminary human health risk calculations, that it is likely that an early action involving institutional controls and/or excavation of sediment/soil from portions of upper and lower Montezuma Creek will be warranted. Therefore, the DOE will prepare a separate streamlined risk evaluation for sediment/soil. If the streamlined risk evaluation indicates early action is warranted, an EE/CA will be prepared. The early action will be pursued if the EE/CA indicates that the action can realistically achieve rapid reductions in the majority of risk, is consistent with the likely final remedy for the site, and can be implemented in a manner that results in overall cost savings. The implementation of any early action for sediment/soil would likely occur in late 1996 or 1997. Similarly, the DOE will pursue an early action for surface water and ground water, if warranted on the basis of risk assessment and ground-water modeling results. Any early action for surface water and ground water would likely occur in 1997 or 1998.

Act ID	Description	Orig Dur	Rem Dur	Early Start	Early Finish
RI140	Submit Draft Final (DF) RI/FS Work Plan	0	0	15SEP95 *	
RI150	RI/FS Work Plan - Final Concurrence	0	0		16OCT95
RI200	Sample Collection	85d	15d	05JUN95 A	29SEP95
RI210	Laboratory Analysis	63d	63d	12JUN95 A	07DEC95
RI220	Data Validation	90d	90d	28SEP95	05FEB96
RI230	Well Installation and Development	20d	20d	16OCT95 *	10NOV95
RI240	New Well Sampling (1st Quarter)	5d	5d	13NOV95	17NOV95
RI250	Lab Analysis - New Wells (1st Quarter)	45d	45d	28NOV95	31JAN96
RI260	New Well Sampling (2nd Quarter)	5d	5d	22JAN96	26JAN96
RI270	Lab Analysis - New Wells (2nd Quarter)	45d	45d	05FEB96	05APR96
RI280	Data Validation - New Wells	21d	21d	08APR96	06MAY96
RI300	Ecological Risk Assessment	142d	142d	11SEP95	29MAR96
RI400	Human Health Risk Assessment	142d	142d	11SEP95	29MAR96
RI500	Ground-Water Modeling	200d	122d	03APR95 A	01MAR96
RI600	Prepare Draft RI Report	142d	142d	06NOV95	24MAY96
RI610	Regulatory Agency Review	42d	42d	28MAY96	25JUL96
RI620	Prepare DF OU III RI Report	42d	42d	26JUL96	24SEP96
RI630	Submit DF Rpt - Stip Pnlty Milestone (SPM)	0	0	19JUN97 *	
RI640	RI Report - Final Concurrence	21d	21d	25SEP96	23OCT96
FS100	Remedial Alternatives Screening	63d	63d	17OCT95	16JAN96
FS105	Remedial Alternatives Evaluation	120d	120d	17JAN96	03JUL96
FS110	Prepare Draft FS Report	64d	64d	03JUL96	02OCT96
FS120	Reg. Review - Draft FS Report	42d	42d	03OCT96	02DEC96
FS130	Prepare DF FS Report	42d	42d	03DEC96	31JAN97
FS140	Submit DF OU III FS Report -SPM	0	0	19JUN97 *	
FS150	FS Report - Final Concurrence	21d	21d	03FEB97	03MAR97
PP100	Prepare Draft Proposed Plan (PP)	100d	100d	08NOV96	01APR97
PP110	Reg. Review - Draft PP	42d	42d	02APR97	30MAY97
PP120	Prepare DF PP	42d	42d	02JUN97	30JUL97
PP130	Submit DF OU III Proposed Plan-SPM	0	0	22MAY98 *	
PP140	PP - Final Concurrence	21d	21d	31JUL97	28AUG97
PP150	PP & RI/FS Report - Public Comment	22d	22d	29AUG97	30SEP97
PP160	Prepare Draft Record of Decision (ROD)	42d	42d	01OCT97	28NOV97
PP170	Reg. Review - Draft ROD	42d	42d	01DEC97	29JAN98
PP180	Prepare DF ROD	42d	42d	30JAN98	30MAR98
PP185	Submit DF OU III ROD-SPM	0	0	11JAN99 *	
PP190	ROD - Final Concurrence	21d	21d	31MAR98	28APR98
RA100	Initiate OU III Remedial Design/Action	0	0	29APR98	

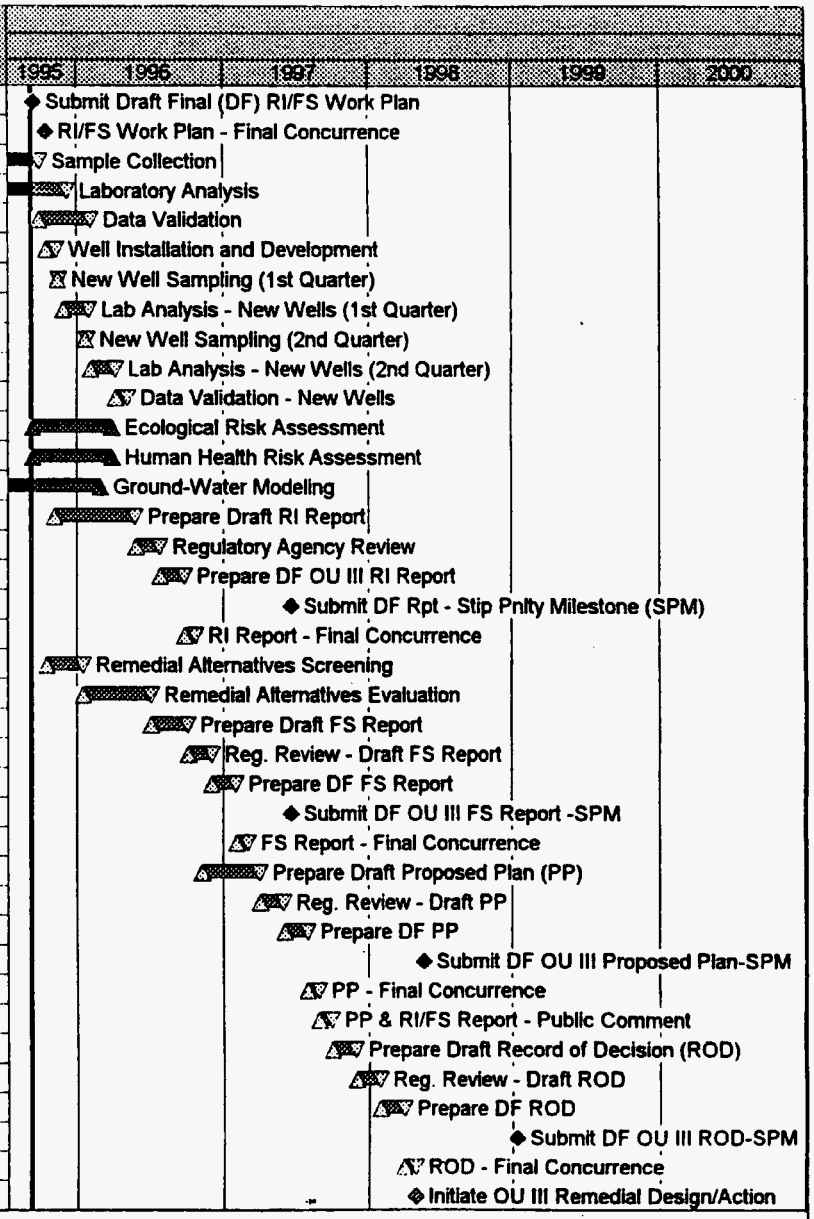

Figure 7.0. OU III Working Schedule

Early start point
Early finish point
Early bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

UNITED STATES DEPARTMENT OF ENERGY
MONTICELLO SURFACE WATER & GROUND WATER
(OPERABLE UNIT III)

Data date 09SEP95
Project name MSG9

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8.0 Documentation

8.1 Administrative Record

The administrative record is the complete body of documents that forms the basis for selecting a CERCLA response action. It serves two primary purposes. First, it limits the judicial review of the adequacy of the selected response action to only those documents in the administrative record. Secondly, it acts as a vehicle for public participation in selecting a response action because it is available for public inspection and comment.

As required by the FFA, DOE has established and is maintaining an administrative record for OU I, OU II, and OU III. The administrative record for all OUs is maintained in accordance with the requirements of Section 113(k) of CERCLA, with current EPA policy and guidelines, and the provisions of the Federal Facilities Agreement.

The administrative record for OU III is kept at two locations. One location is at DOE-GJPO in the Technical Library's Public Reading Room; the other is at the Rust Office in Monticello, Utah. A copy of each document is placed in the administrative record, which is updated quarterly and transmitted to EPA and the State. The update includes an Index of Documents in the complete administrative record.

The administrative record usually only contains the final version of documents. However, EPA makes final determination, after consultation with the State, of whether a document is appropriate for inclusion in the administrative record. The Index of Documents provides a complete listing of documents and information in the administrative record. Examples of documents in the administrative record are listed below:

- RI/FS Work Plan
- RI/FS Sampling and Analysis Plan
- RI/FS Quality Assurance Project Plan
- Baseline Risk Assessment Report
- Remedial Investigation Report
- Feasibility Study Report
- Work Plans and Reports for Treatability Studies
- Proposed Plan
- Record of Decision (draft and final version), to include the Responsiveness Summary.

8.2 Information Repository

EPA requires that an information repository be established at facilities undergoing response actions. The information repository contains all the information on response activities that is available to the public throughout the life of the project. This includes all types of information about the site, the CERCLA program, and information describing the response action.

DOE has established an information repository for OU III that is kept with the information repositories for OUs I and II. The information repository for OU III is kept at the same locations as the Administrative Record.

Materials in the information repository overlap with the administrative record. However, the information repository contains additional information that is not in the administrative record, such as remedial design and remedial action documents. The administrative record generally contains only those documents that form the basis for selecting a response action (i.e., pre-ROD and ROD information). As with the administrative record, EPA makes final determination, after consultation with the State, of whether a document is appropriate for inclusion in the information repository. The Index of Documents provides a complete listing of documents in the information repository. Examples of documents in the information repository are listed below:

- Press releases and fact sheets generated about the response action
- Community Relations Plan
- RI/FS Work Plan
- RI Report
- FS Report (draft and final)
- Remedial Design Work Plan
- Remedial Design
- Federal Facilities Agreement
- ROD
- Documentation of site sampling results
- General information about the CERCLA program
- DOE Five-Year Plans
- DOE Site-Specific Plan

9.0 References

40 CFR Part 192, U.S. Environmental Protection Agency, "Standards for Remedial Action at Inactive Uranium Processing Site," *U.S. Code of Federal Regulations*.

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